TECHNICAL SUPPORT DOCUMENT (TSD): ENERGY EFFICIENCY PROGRAM FOR COMMERCIAL AND INDUSTRIAL EQUIPMENT: EFFICIENCY STANDARDS FOR COMMERCIAL HEATING, AIR-CONDITIONING, AND WATER HEATING EQUIPMENT

Including:

Packaged Terminal Air-Conditioners and Packaged Terminal Heat Pumps
Small Commercial Packaged Boilers
Three-Phase Air-Conditioners and Heat Pumps <65,000 Btu/h
Single-Package Vertical Air Conditioners and Single-Package Vertical Heat Pumps <65,000 Btu/h

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U.S. Department of Energy
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This Document was prepared for the Department of Energy
by staff members of
Navigant Consulting, Inc.
and
Pacific Northwest National Laboratory

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NOMENCLATURE

Acronyms and Abbreviations

AC	air conditioner
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CEE	Center for Energy and Environment
COP	coefficient of performance
DOE	U.S. Department of Energy
EER	energy efficiency ratio
EPACT	Energy Policy Act
EPCA	Energy Policy and Conservation Act
FLEOH	full-load equivalent operating hours
GAMA	Gas Appliance Manufacturers Association
HI	Hydronics Institute Division of GAMA
hp	horsepower
HP	heat pump
HSPF	heating seasonal performance factor
HVAC	heating, ventilating and air conditioning
I=B=R	Institute of Boilers and Radiation Manufacturers
IESNA	Illuminating Engineering Society of North America
LCC	life-cycle cost
NA	not applicable
NC	not calculated
n.d.	no date
Max NPV	maximum net present value
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
SEER	seasonal energy efficiency ratio
SPVAC	single-package vertical air conditioner
SPVHP	single-package vertical heat pump
SPVU	single package vertical unit
TSD	technical support document

Symbols

ΔE	differential between combustion efficiency and thermal efficiency
E_C	combustion efficiency
E_T	thermal efficiency
μ	arithmetic mean
σ	standard deviation

Units

Btu	British Thermal Unit
h	hour
kWh	kilowatt-hour
kBtu	kilo Btu (10^3 Btu)
quad	quadrillion Btu (10^{15} Btu)
sf	square feet
TBtu	tera Btu (10^{12} Btu)
W	watt
yr	year

CHAPTER 1. INTRODUCTION

1.1 OVERVIEW

On October 29, 1999, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)'s Board of Directors approved American National Standards Institute (ANSI)/ ASHRAE/Illuminating Engineering Society of North America (IESNA) Standard 90.1-1999, which addressed efficiency levels for 34 categories of commercial heating, ventilating and air-conditioning (HVAC) and water heating equipment covered by the Energy Policy and Conservation Act (EPCA).[10] The new Standard 90.1 (Standard 90.1-1999) revised the efficiency levels of the existing Standard 90.1-1989 for certain equipment. For the remaining equipment, ASHRAE left the preexisting levels in place, after considering revision of the levels for some equipment and deferring consideration of others.

Following the publication of Standard 90.1-1999, the U.S Department of Energy (the Department or DOE) performed a screening analysis that covered 24 of the categories of equipment to help decide what action it would take with respect to the new efficiency levels. For each of these types of equipment, the screening analysis examined a range of efficiency levels that included the levels specified in EPCA and Standard 90.1-1999, as well as the levels associated with the lowest life-cycle cost (LCC). The analysis is summarized in the report "Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment" (screening analysis) and estimates the annual national energy consumption and the potential for energy savings that would result if the Energy Policy Act (EPACT)-covered products were to meet these efficiency levels.[25] The analysis also estimates additional energy-savings potential for the EPACT-covered products if they were to exceed the efficiency levels prescribed in Standard 90.1-1999. The baselines for the comparison were the corresponding levels specified in Standard 90.1-1999 and EPCA.

Following completion of the screening analysis, the Department published a notice that described the screening analysis and announced its public availability. For each equipment category for which ASHRAE adopted or considered a revised standard level, the notice stated whether the Department was inclined to immediately adopt the standard level in Standard 90.1-1999, or to undertake a more thorough analysis to determine if a more stringent level was warranted. For the equipment categories that ASHRAE did not address in revising Standard 90.1 – namely, three-phase air conditioners (ACs) and heat pumps (HPs) with capacities less than 65,000 Btu per hour – DOE stated that it had tentatively decided to take no action until ASHRAE had amended Standard 90.1's efficiency levels for these types of equipment. Finally, the notice published on May 15, 2000, announced a public meeting and invited written comment on the screening analysis and DOE's planned actions. 65 FR 30929 (May 15, 2000).

The Department adopted the efficiency levels in Standard 90.1-1999 as Federal standards to replace existing EPCA levels for 18 equipment categories of commercial air conditioners, heat pumps, furnaces, water heaters, and hot water storage tanks following the public meeting on July 11, 2000. For electric water heaters, DOE rejected the Standard 90.1-1999 level, leaving the EPCA level in place. 66 FR 3335, 3336-37, 3349-52 (January 12, 2001) (the "January 2001 final rule").

For 11 other categories of commercial equipment, the Department stated it would evaluate whether to adopt more stringent standards than those contained in Standard 90.1-1999. 66 FR 3336-38, 3349-52. The Department selected these categories of equipment for further evaluation because the screening analysis indicated at least a reasonable possibility of finding "clear and convincing evidence" that more stringent standards "would be technologically feasible and economically justified and would result in significant additional conservation of energy." 66 FR 3349. These are the criteria EPCA prescribes for the adoption of standards more stringent than those in Standard 90.1. (42 U.S.C. 6313(a)(6)(A)) The Department stated that it could discontinue its evaluation of any of these types of equipment, however, and adopt the Standard 90.1-1999 efficiency level, whenever it concluded that these criteria are not likely to be satisfied. 66 FR 3348. However, DOE had previously indicated that it would take such action only after seeking public comment. 65 FR 30932.

For three-phase central air conditioners and central air-conditioning heat pumps less than 65,000 Btu/h (three-phase ACs), DOE took no action because ASHRAE had not addressed these products, but encouraged ASHRAE to amend its efficiency levels for this equipment in conjunction with the then-pending DOE standards rulemaking for similar, single-phase residential products, and stated that DOE would act once ASHRAE had adopted such amendments.

The Department initially considered single-package vertical air conditioners (SPVACs) and single-package vertical heat pumps (SPVHPs) in the November 24, 1999, residential central air conditioner (CAC) notice of proposed rulemaking (NOPR). In the October 5, 2000, NOPR for residential CACs, DOE determined that single-package vertical units (SPVUs) were commercial products not subject to residential efficiency standards. Subsequently, DOE included these products as part of their evaluation of commercial unitary air-conditioning and heat pump equipment (CUAC and HP) rulemaking and the HVAC equipment under the ASHRAE products rulemaking dependent upon capacity. On August 8, 2005, EPACT 2005 (Pub. L. 109-58) was signed into law, which contains energy conservation standards for small (≥65,000 Btu/h to <135,000 Btu/h), large (≥135,000 Btu/h to <240,000 Btu/h), and very large (≥240,000 to <760,000) commercial package air conditioners and heat pumps. The signing of EPACT 2005 required the classification of SPVUs into two distinct capacity categories: those products <65,000 Btu/h and those products ≥65,000 Btu/h to <760,000 Btu/h. The Department will continue its evaluation of products <65,000 Btu/h, which are included in this TSD.

The four products—packaged terminal air-conditioners and heat pumps (PTACs and PTHPs), small commercial packaged boilers, three-phase ACs and HPs <65,000 Btu/h, and SPVUs <65,000 Btu/h—are the subjects of this technical support document (TSD). The TSD reviews the calculated potential national energy savings contained in the screening analysis, summarizes new data obtained and new analyses performed after the screening analysis, and provides information supporting DOE's current action regarding each of the five covered products.

1.2 STRUCTURE OF THE DOCUMENT

The TSD consists of six chapters. Chapter 1 includes an introduction describing DOE's authority to take action on EPACT-covered products for which ASHRAE amends efficiency levels prescribed in Standard 90.1-1989, background information summarizing the history of DOE action to date, and the purpose of this TSD. The subsequent chapters give an overview of the history of each product category, describe the individual products and product classes being evaluated, summarize the potential national energy savings, and describe the issues involved with and information relative to DOE's current action.

Chapter 1	Introduction
Chapter 2	Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps
Chapter 3	Small Commercial Packaged Boilers
Chapter 4	Three-Phase Air-Conditioners and Heat Pumps <65,000 Btu/h
Chapter 5	Single-Package Vertical Air Conditioners and Heat Pumps <65,000 Btu/h
Appendices	Appendix A: PTAC and PTHP Energy Savings Analyses
	Appendix A-1 – Revised Cooling Mode Energy Savings Analysis
	Appendix A-2 – Heating Mode Energy Savings Analysis

CHAPTER 2. PACKAGED TERMINAL AIR-CONDITIONERS AND PACKAGED TERMINAL HEAT PUMPS

2.1 BACKGROUND

PTACs and PTHPs are self-contained air-conditioning units that provide cooling, and in some cases heating, and are installed inside a sleeve placed in an exterior wall opening in commercial buildings. They are primarily used to provide space conditioning for commercial facilities such as hotels, motels, hospitals, nursing homes, apartments, dormitories, schools, and offices.

EPCA Section 340 (10)(A) defines a PTAC as "a wall sleeve and a separate unencased combination of heating and cooling assemblies specified by the builder and intended for mounting through the wall. It includes a prime source of refrigeration, separable outdoor louvers, forced ventilation, and heating availability by builder's choice of hot water, steam, or electricity." (42USC6311(10)(A))

Likewise, EPCA Section 340 (10)(B) defines a PTHP as "a packaged terminal air conditioner that utilizes reverse cycle refrigeration as its prime heat source and should have supplementary heat source available to builders with the choice of hot water, steam, or electric resistant heat." Energy efficiency standards are set forth in EPCA for PTACs and PTHPs in Section 342 (a)(3). (42USC6313(a)(3)) The efficiency requirements in the statute correspond to the levels in Standard 90.1 as in effect on October 24, 1992, and are given as formulas for energy efficiency ratio (EER) for cooling and coefficient of performance (COP) for heating based on the capacity of the product (see Table 1, Figure 1, and Figure 2).

Table 1. Comparison of Energy Efficiency Standards for PTACs and PTHPs

Category	Efficiency (EER/COP)		
	EPCA	Standard 90.1-1999	
		New Construction	Replacement†
PTAC – Cooling Mode	10.0 – (0.16 x Cap/1000)* EER	12.5 – (0.213 x Cap/1000)* EER	10.9 – (0.213 x Cap/1000)* EER
PTHP – Cooling Mode	10.0 – (0.16 x Cap/1000)* EER	12.3 – (0.213 x Cap/1000)* EER	10.8 – (0.213 x Cap/1000)* EER
PTHP – Heating Mode	1.3 + (0.16 x EER)** COP	3.2 – (0.026 x Cap/1000))*COP	2.9 – (0.026 x Cap/1000)* COP

Sources: EPCA and Standard 90.1-1999.

* Cap means the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation.

** EER is the minimum cooling EER.

† According to Standard 90.1-1999 Table 6.2.1D, Footnote b, replacement efficiencies apply only to units (1) factory labeled as follows: "Manufactured for Replacement Applications Only; Not to be Installed in New Construction Projects"; and (2) with existing sleeves less than 16 in. high and less than 42 in. wide.

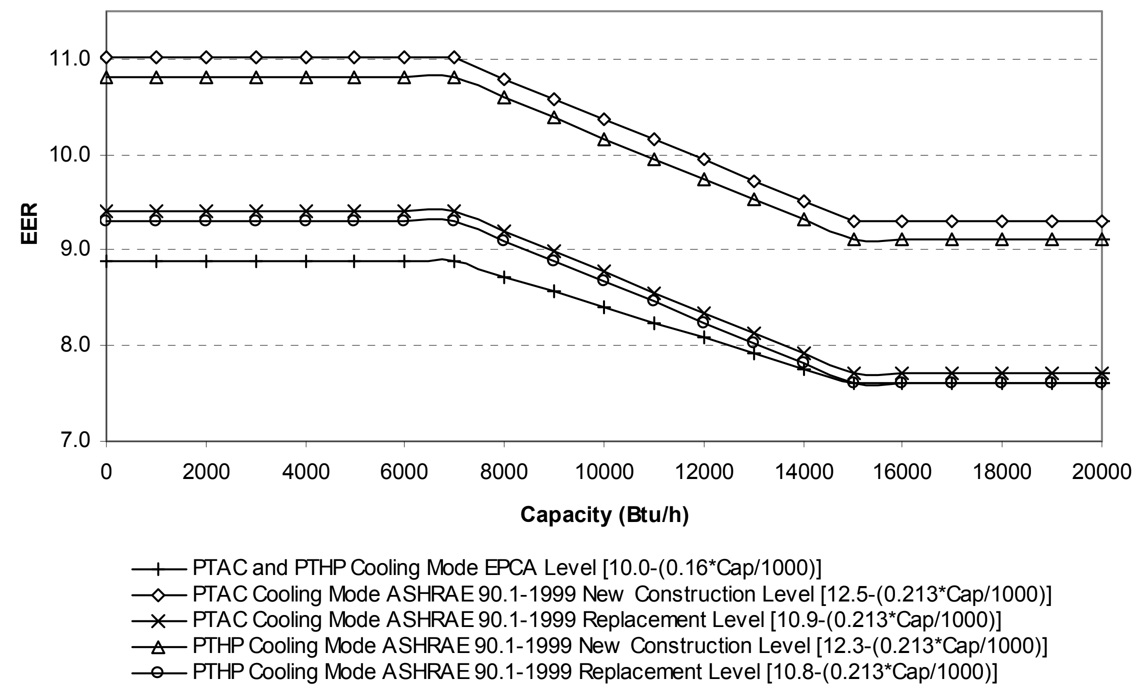


Figure 1. Comparison of Energy Efficiency Standards for PTACs and PTHPs – Cooling Mode

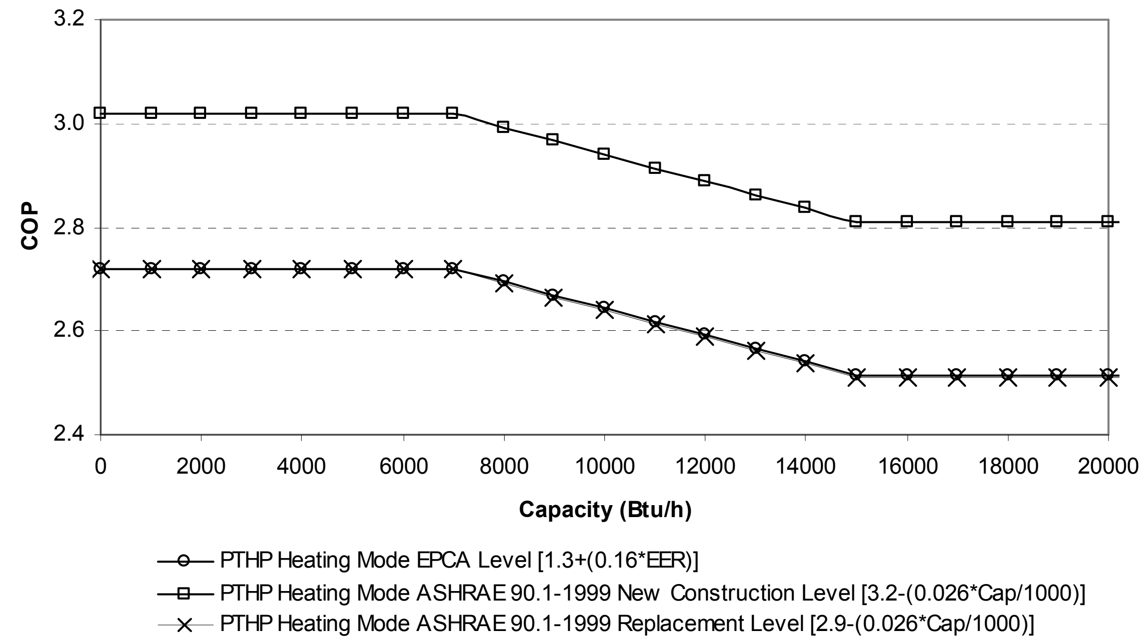


Figure 2. Comparison of Energy Efficiency Standards for PTHPs – Heating Mode

ASHRAE's Board of Directors gave final approval to certain revisions to Standard 90.1-1989 on October 29, 1999. For PTACs and PTHPs, ASHRAE increased the efficiency standards and divided the standards for each category into separate levels for new construction and replacement installations (see Table 1). In addition to the differences in installation, the distinctions between new construction and replacement products are in their labeling and sleeve size. To qualify for the efficiency levels applicable to replacement products, PTACs and PTHPs must have a sleeve size less than 16 inches high and less than 42 inches wide, and be labeled as being for replacement applications only.

The PTAC and PTHP energy efficiency levels for EPCA, new construction Standard 90.1-1999 and maximum net present value (Max NPV) (from the screening analysis) are summarized for four PTAC and PTHP capacity categories in Table 2 below.

Table 2. Comparison of Cooling Energy Efficiency Levels for PTACs and PTHPs

Category	Efficiency (EER)		
	EPCA	Standard 90.1-1999*	Max NPV*
PTAC <7 kBtu/h	8.9	9.4	9.4
PTAC 7-10 kBtu/h	8.6	9.0	10.6
PTAC 10-13 kBtu/h	8.1	8.3	10.2
PTAC >13 kBtu/h	7.8	7.9	9.5
PTHP <7 kBtu/h	8.9	9.3	9.3
PTHP 7-10 kBtu/h	8.6	8.9	10.6
PTHP 10-13 kBtu/h	8.1	8.2	9.7
PTHP >13 kBtu/h	7.8	7.8	9.3

Sources: Screening Analysis (DOE 2000).
* At new construction levels only.

2.2 ENERGY SAVINGS

This section examines the national potential energy savings estimated in the screening analysis, describes the new analysis that updates the cooling mode energy savings estimates of the screening analysis, and summarizes the new heating mode energy savings analysis.

The purpose of the screening analysis was to examine the efficiency levels specified in EPCA and Standard 90.1-1999 for the EPACT-covered products, as well as more efficient levels, including those associated with the most energy efficient products available on the market. The energy savings estimates contained in the screening analysis include savings for PTACs and PTHPs operating in the cooling mode only. The potential energy savings estimates for PTACs and PTHPs operating in the cooling mode in the screening analysis are summarized in Table 3.[1]

[1] Energy savings for PTHPs operating in the heating mode were not calculated in the Screening Analysis.

Table 3. Potential Energy Savings for PTACs and PTHPs Based on the Standard 90.1-1999 Replacement Efficiency Level as a Baseline*

Category	Potential Energy Savings (quads)	
	Standard 90.1-1999 Relative to EPCA	**Max NPV Relative to Standard 90.1-1999**
PTACs – Cooling Mode	0.068	0.312
PTHPs – Cooling Mode	0.039	0.249
PTHPs – Heating Mode	NC	NC
TOTAL	**0.107**	**0.561**

Source: Screening Analysis (DOE 2000, Table 3.12).[25]
* Assumes Standard 90.1-1999 standards for Replacement apply to 100% of the units.

Table 3 shows the results of the energy savings calculations as presented in Table 3.12 of the screening analysis. The Department subsequently used these values in developing the summary chart of potential energy savings in the January 12, 2001, final rule. 66 FR 3336. Table 3 shows the potential energy savings of 0.561 quads for developing a standard at the Max NPV level, which is higher than that of Standard 90.1-1999. The potential energy savings for the Standard 90.1-1999 replacement efficiency levels relative to the EPCA efficiency levels are 0.107 quads as shown in Table 3. These savings are a result of assuming 100 percent of the packaged terminal products increasing in efficiency from the EPCA baseline levels to the Standard 90.1-1999 replacement efficiency levels only.

2.2.1 Revised Cooling Mode Energy Savings Analysis Summary

This section describes the revised analysis that updates the cooling mode energy savings estimates for PTACs and PTHPs in the screening analysis. The methodology and assumptions used for the revised cooling mode energy savings analysis are presented in Appendix A1. In Standard 90.1-1999, the replacement efficiency level only applies to products with sleeve sizes less than 16 inches in height and 42 inches in width. The original screening analysis lumps the PTAC and PTHP units together without regard to product dimensions. The assumptions made in the revised analysis are listed in Table 4 and described below.

Table 4. Differences in Assumptions for PTAC and PTHP Cooling-Mode Energy Savings

Category	Screening Analysis	Revised Cooling Mode Energy Savings Analysis
Methodology	• Savings are calculated under two different scenarios – using Standard 90.1-1999 new construction efficiency levels and replacement efficiency levels.*	• Savings are calculated using one scenario – market weighted shipments used to calculate savings for both Standard 90.1-1999 efficiency levels.
Shipments	• All shipments grouped together regardless of product size. • 100% of shipments used in both calculation scenarios. • Shipment fraction for smaller products not provided by ARI and unknown.	• 85% of shipments estimated to be larger products, and 15% smaller products. • Shipment estimates based on average of 1999-2000 shipments from ARI and Census data.
Cooling Load	• Space cooling load not analyzed separately from other packaged unitary equipment.	• Space cooling load based on estimated cooling load for lodging building category.
Analysis Period for Developing a Higher Standard	• 2004-2030	• 2008-2030, assumes DOE completing a rulemaking by 2004 with an effective date of 2008.

* As shown in the Screening Analysis (DOE 2000, Appendix D).[25]

The Department has re-evaluated the energy savings estimates in the screening analysis for PTAC and PTHP products operating in the cooling mode based on new market information (see Table 4 for a list of new assumptions). The revised cooling mode energy savings analysis estimates the size of the market for larger sized packaged terminal products to be 85 percent of current U.S. shipments and 15 percent for smaller size packaged terminal products based on average shipment data from 1999 to 2001 from ARI and Census information. Also, the shipments were allocated among the two Standard 90.1-1999 efficiency levels – larger products were assigned the Standard 90.1-1999 new construction efficiency level and smaller products were assigned the Standard 90.1-1999 replacement efficiency level. Furthermore, the cooling load estimates in the updated analysis reflect cooling loads for lodging facilities only because the majority of PTAC and PTHP installations are in lodging (i.e., apartments, hotels, motels, and assisted living residences). In addition, DOE updated the effective dates for adopting standards higher than the Standard 90.1-1999 based on the earliest possible timeframes for conducting a rulemaking and making standards effective.

2.2.2 Heating Mode Energy Savings Analysis Summary

The Department also conducted an analysis to examine the additional energy savings potential from improvements in the heating efficiency of PTHPs, since this was not included in the screening analysis. DOE estimates that PTHPs represent approximately 45 percent of the total market for packaged terminal equipment. Also, the heating mode energy savings analysis assumes that 85 percent of the PTHP market is in the larger product size category, while 15 percent of the PTHP market is in the smaller category, similar to the assumptions made for PTACs. The methodology and assumptions used for the heating mode energy savings analysis are presented in Appendix A-2.

2.2.3 Revised Potential Energy Savings for PTACs and PTHPs Summary

Table 5 demonstrates the revised potential energy savings for PTACs and PTHPs for both cooling and heating mode relative to EPCA and Standard 90.1-1999. Table 5 also shows the potential energy savings when adopting the market maximum efficiency levels for packaged terminal products relative to the Standard 90.1-1999 efficiency levels.

Table 5. Updated Potential Energy Savings for PTACs and PTHPs

Category	Potential Energy Savings (quads)			
	Standard 90.1-1999 Relative to EPCA		Market Maximum Relative to Standard 90.1-1999	
	New Construction (Large PTHPs)	Replacement (Small PTHPs)	New Construction (Large PTHPs)	Replacement (Small PTHPs)
PTAC & PTHP Cooling Mode	0.450*	0.012*	0.048**	0.055†
PTHP Heating Mode	0.037*	0	0.031**	0.006†
TOTAL	**0.499**		**0.139**	

* Assumes having an effective date for the adopted ASHRAE standard in 2005 with energy savings calculated to 2030.
** Values represent adopting the market maximum efficiency level in 2008 relative to adopting the Standard 90.1-1999 New Construction efficiency levels in 2005.
† Values represent adopting the market maximum efficiency level in 2008 relative to adopting the Standard 90.1-1999 Replacement efficiency level in 2005.

The adoption of Standard 90.1-1999 efficiency levels for products with sleeve sizes greater than or equal to 16”x42” is estimated to provide potential energy savings of 0.499 quads of energy relative to the EPCA standard levels in cooling mode. The Department estimates that the adoption of Standard 90.1-1999 replacement efficiency levels for smaller sleeve-size packaged terminal products will save an additional 0.012

quads of energy for cooling operation. The revised cooling mode energy savings analysis also shows that adopting the market maximum efficiency levels for packaged terminal products compared to the Standard 90.1 efficiency levels gives an additional potential energy savings of 0.048 quads for the larger sleeve size products and an additional 0.055 quads for the smaller sleeve size products (assuming that market maximum for these products would bring them up to the efficiency required by Standard 90.1-1999 for the 16" x 42" or larger products by 2008).

The heating mode energy savings analysis shows that adoption of Standard 90.1-1999 efficiency levels for products with sleeve sizes greater than or equal to 16"x42" is estimated to provide savings benefits of 0.037 quads of energy relative to the EPCA standard levels. Adoption of Standard 90.1-1999 efficiency levels for smaller packaged terminal products is expected to save zero quads of energy, since the heating COP efficiency levels for these smaller sleeve size PTHP products are identical to the current EPCA requirements. Since there is no change in efficiency levels, this analysis assumes that there are zero heating energy savings from adoption of the Standard 90.1-1999 heating efficiencies for these products. DOE assumed that, independent of adoption of standards, the heating efficiency for the fraction of the market that is represented by the small size PTHPs would meet the Standard 90.1-1999 efficiency levels by 2008.

In summary, the potential cooling-mode energy savings in seeking a standard above Standard 90.1-1999 is estimated in the Screening Analysis to be 0.561 quads. The revised energy savings analysis calculated the revised cooling mode potential energy savings analysis to be 0.462 quads when compared to EPCA. The revised potential cooling-mode energy savings in seeking a standard above Standard 90.1-1999 is estimated to be 0.103 quads. Furthermore, the total potential energy savings (heating mode and cooling mode) in adopting a standard above the Standard 90.1-1999 efficiency levels is estimated to be 0.139 quads.

2.3 ISSUES IMPACTING POTENTIAL ENERGY CONSERVATION STANDARDS

One of the factors that DOE considers in developing priorities and establishing schedules for conducting rulemakings is "evidence of energy efficiency gains in the market absent new or revised standards." Evidence of such gain exists for PTACs and PTHPs. An examination of the January 2003 ARI Directory for PTACs and PTHPs reveals that 52 percent of the listed PTACs are at or above the Standard 90.1-1999 new construction efficiency level and 98 percent of the listed PTACs are at or above the Standard 90.1-1999 replacement efficiency level (see Figure 3).[4] Furthermore, 72 percent of the listed PTHPs are at or above the Standard 90.1-1999 new construction efficiency level and 99 percent of the listed PTHPs are at or above the Standard 90.1-1999 replacement efficiency level (see Figure 4).[5] Although the data do not represent information on actual shipments of PTACs and PTHPs, they do suggest that manufacturers have already been manufacturing the equipment at these higher efficiency levels without a requirement to do so.

This information suggests that some of the potential energy savings estimated in the previous section may be achieved in the absence of standards that exceed the levels in Standard 90.1-99, because a substantial part of the PTAC and PTHP market has already moved to higher efficiency levels.

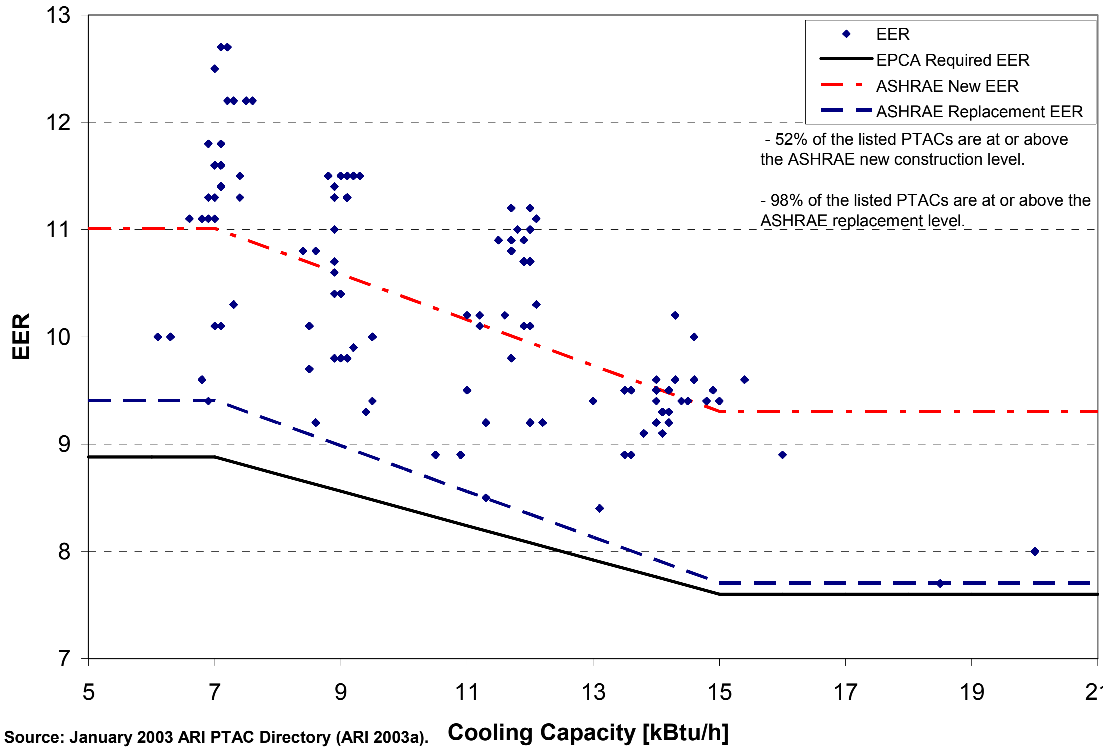
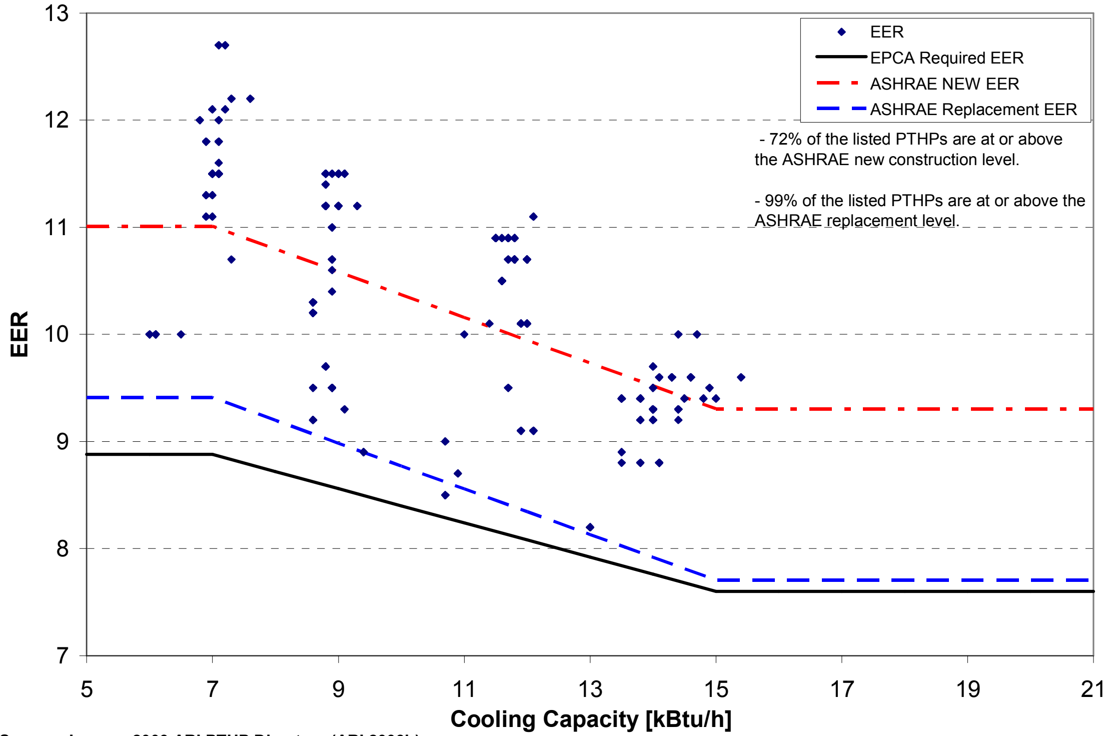


Figure 3: Current Efficiency Levels for PTACs



Source: January 2003 ARI PTHP Directory (ARI 2003b).

Figure 4: Current Efficiency Levels for PTHPs

CHAPTER 3. COMMERCIAL BOILERS

3.1 BACKGROUND

Commercial boilers (also called commercial packaged boilers) are used to provide heating for commercial facilities by heating water and distributing the water in the form of steam or hot water. Commercial boilers are differentiated from residential boilers by their gross output capacity – residential boilers have a capacity of up to 300 kBtu/h while commercial boilers have capacities of 300 kBtu/h or larger. Commercial boilers can be classified into several categories, including oil-fired or gas-fired boilers, steam or hot-water boilers, and small (300 kBtu/h to 2,500 kBtu/h) or large (>2,500 kBtu/h) commercial boilers.

EPCA provides efficiency standards for commercial packaged boilers. EPCA Section 340 (11)(B) defines a packaged boiler as "a boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls; usually shipped in one or more sections." (42USC6311(11)(B)) The efficiency of a commercial boiler can be expressed in one of two ways – combustion efficiency (E_C) or thermal efficiency (E_T). E_C (sometimes referred to as "fuel efficiency") is a measure of a the ability to extract heat from the fuel and is defined as 100 percent minus flue losses (or stack losses).[15] E_C measures the heat loss through the boiler's stack and takes into consideration incomplete fuel combustion. Flue losses include dry flue gas, incomplete combustion, and uncondensed water vapor formed by the combustion of hydrogen.[20] E_C ranges from 75 percent to 86 percent for most non-condensing mechanically fired boilers.[9]

In contrast, E_T (sometimes referred to as "overall efficiency", "boiler efficiency" or "fuel-to-steam efficiency") is a measure of a boiler's ability to provide useful heat and is defined as the ratio of energy output to energy input. E_T can be calculated from a boiler rating by dividing the gross output value (total heat transferred to water or stream) by the gross input value (higher heating value of fuel consumed).[18] In contrast to E_C [2], E_T accounts for radiation losses and convection losses through the boiler's shell (i.e., jacket losses or case losses) and heat exchanger efficiency. E_T is a more accurate metric for describing the performance of boilers from an energy efficiency point of view because it takes into account the useful output of either steam or hot water that is produced by the boiler. E_T is mathematically related to E_C with the equation $E_C = E_T$ – jacket loss. However, the amount of heat loss through a boiler's shell (i.e., jacket loss) varies depending on the boiler's design and construction.

Minimum efficiency levels for commercial boilers in EPCA are 80 percent combustion efficiency (E_C) for gas-fired commercial boilers (42USC6313(a)(4)(C)) and 83 percent E_C for oil-fired commercial boilers (42USC6313(a)(4)(D)) (see Table 6). Minimum efficiency levels in Standard 90.1-1989 were the same as the EPCA efficiency levels. During the development of Standard 90.1-1999, ASHRAE changed the efficiency

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[2] Combustion efficiency levels as specified in EPCA.

metric from E_C to E_T for small commercial boilers. For large commercial boilers, ASHRAE maintained the combustion efficiency metric.

In developing Standard 90.1-1999, ASHRAE chose a 5 percent differential between E_C and E_T (ΔE) for hot water boilers that met an 80 percent combustion efficiency. Therefore, for small commercial boilers (≥300 and ≤2,500 kBtu/h in capacity), ASHRAE, based on input and data provided by GAMA, adopted a 75 percent E_T level for small gas-fired boilers which was believed to be consistent with the EPACT 92 minimum standard (80 percent E_C – 5 percent ΔE = 75 percent E_T) and a 78 percent E_T level for small oil-fired boilers (83 percent E_C – 5 percent ΔE = 78 percent E_T) as part of Standard 90.1-1999. Oil-fired boilers were not explicitly analyzed as part of the ASHRAE process, but instead were assumed to have both thermal and combustion efficiencies three percentage points higher than that finally established for gas-fired boilers.

Table 6. Comparison of Energy Efficiency Standards for Commercial Boilers

Category	**Efficiency**	
	EPCA	Standard 90.1-1999
Small Gas-Fired (300-2,500 kBtu/h)	80.0% E_C	75.0% E_t
Small Oil-Fired (300-2,500 kBtu/h)	83.0% E_C	78.0% E_t

Sources: EPCA and Standard 90.1-1999.

3.2 ENERGY SAVINGS

The screening analysis shows the estimated potential national energy savings for gas-fired commercial boilers with respect to the EPCA efficiency baseline. The Department did not analyze energy savings for oil-fired commercial boilers in the screening analysis. For small commercial hot water boilers, ASHRAE changed the minimum efficiency in Standard 90.1-1999 from the 80 percent E_C (as specified in EPCA) to 75 percent E_T. For gas-fired products, ASHRAE implied that this 5 percent point differential was characteristic of the efficiency ratings difference for products with an 80 percent E_C rating, and the screening analysis therefore stated there was no energy savings in adopting Standard 90.1-1999 levels. However, there is an estimated 0.064 quads of potential energy savings reported in the Screening Analysis for adopting Standard 90.1-1999 over the EPCA levels for small gas-fired commercial steam boilers (see Table 7). This is because the GAMA data for gas-fired steam boilers suggested that, for baseline products (80 percent E_C), a 72 percent E_T was more representative of their thermal efficiency. Thus this 8 percent point differential was used in describing the baseline thermal efficiency for the three categories of small steam boiler products (400, 800, and 1,500 kBtu/h capacities). These products are then shown as going from a 72 percent E_T value in EPCA to a 75 percent E_T value in Standard 90.1-1999[25], even though the EPCA baseline efficiency specified is 80 percent E_C for these boilers. The Department also calculated energy savings for adopting various efficiency levels above the Standard 90.1-1999 levels in the screening analysis. Energy savings resulting from adopting the Max NPV efficiency levels relative to the Standard 90.1-1999 levels are summarized in Table 7.

Table 7. Potential Energy Savings for Small Commercial Boilers

Category	EPCA	Standard 90.1-1999 Relative to EPCA		Max NPV Relative to 90.1-1999	
	E_C (%)	E_T (%)	Energy Savings (quads)	E_T (%)	Energy Savings (quads)
Small Gas-Fired Boilers (300-2,500 kBtu/h)	80.0	75.0	0.064	78.7	0.200
Small Oil-Fired Boilers (300-2,500 kBtu/h)	83.0	81.0	NC	-	NC

Sources: EPCA and Screening Analysis (DOE 2000).
* Combustion efficiency.

The screening analysis estimates that the Max NPV efficiency levels (i.e., the efficiency levels for the lowest life-cycle cost) occur at an average of 78.7 percent E_T for all small gas-fired commercial boilers. The corresponding estimated energy savings for the Max NPV efficiency levels relative to Standard 90.1-1999 is 0.200 quads for small gas-fired boilers (see Table 7).

3.3 ISSUES IMPACTING POTENTIAL ENERGY CONSERVATION STANDARDS

3.3.1 Small Commercial Boilers ($\geq$300 and < 2,500 kBtu/h)

A significant issue regarding small commercial boilers is whether ASHRAE lowered the standard in changing from an 80 percent E_C level specified in EPCA to a 75 percent E_T level specified by Standard 90.1-1999 for small gas-fired boilers, and an 83 percent E_C level specified by EPCA to a 78 percent E_T level specified by Standard 90.1-1999 for small oil-fired boilers. The Department's understanding is that the 5 percent differential between the two efficiency metrics corresponds to the largest difference between combustion and thermal efficiency levels for any boiler ratings reported in the Institute of Boilers and Radiation Manufacturers (I=B=R) directory and complied with the existing 80 percent E_C efficiency level specified by EPCA. Moreover, the differential was not based on a direct correlation between E_C and E_T. However, the Department's analysis of the 2005 I=B=R directory for commercial boilers shows that the average differential between E_C and E_T for commercial boilers listed (gas and oil-fired boilers of all capacities) is 2.28 percent (see Table 8).[21] The following section describes the analysis of the 2005 I=B=R ratings directory and quantifies the differential between E_C and E_T based on available data.

4.3.1.1 I=B=R Commercial Boiler Ratings Directory Analysis

The I=B=R ratings directory is produced by the Hydronics Institute (HI) Division of the Gas Appliance Manufacturers Association (GAMA) and includes boilers, baseboard radiation, and finned tube radiation products. The Department chose the I=B=R ratings directory for the analysis because the directory is the best available source for E_T ratings[3] across the boiler industry. For this analysis, DOE used only the commercial boiler section of the directory (i.e., boilers with capacities of 300 kBtu/h or larger). The 2005 I=B=R ratings directory lists 1715 commercial boiler models from 25 manufacturers. However, the directory has certain features and peculiarities/inconsistencies which limited the number of boilers that could be examined in the analysis.

First, some of the boilers are designated with a "#" symbol before the model series name indicating that these boilers are tested for E_C under test procedures specified in the ANSI Z21.13 test method.[7] The remaining boilers (those without a "#" symbol before the model series name) are tested for both E_C and E_T under test procedures specified in the HI test method.[19] The Department is unaware of any rationale that would cause commercial boiler manufacturers to use the HI test method over the ANSI Z21.13 test method. E_T values are calculated by dividing the gross output value by the nameplate input rating[4] for only those boilers tested under the HI test procedure (boilers without the "#" symbol before the model series name). E_T values cannot be calculated for boilers tested under ANSI Z21.13 because of the difference in the method of testing. Therefore, this analysis excluded the boiler models certified under ANSI Z21.13. The remaining boilers represent 62.6 percent of the boilers in the directory and include 1075 commercial boilers.

Second, some of the boiler ratings in the directory show $E_T \geq E_C$, which is physically impossible. E_T is always less than E_C because E_T includes the effects of jacket losses and E_C does not. These anomalous ratings are likely due to HI's de-rating procedures, manufacturers' interpolation of results.[27] Any significant variation is instrument calibration and test procedures leads to erroneous readings. Specifically, the HI test procedure allows boiler manufacturers to de-rate boilers by 3 percent for boilers using dual fuel burners (HI 1989). Also, manufacturers may interpolate ratings for model series without actually testing the entire model line (Bixby 1999 as cited in Ware 2000).[27] Manufacturers are also allowed to "self-select" boilers they certify to HI which could result in misleading results.[27] In addition, HI's testing program is a "witnessed" boiler test at a manufacturer's facility, rather than at a certified testing facility exclusively used for HI boiler testing (Demaria 1999 as cited in Ware 2000). This can result in variation in instrument calibration and variation in testing. Finally, calibration of testing instruments may differ among the manufacturer test facilities even within the requirements of the HI test standard (HI 1989 as cited in Ware 2000). All of these factors potentially contribute to errors in the boiler ratings. For these reasons, this analysis

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[3] E_T values are calculated by dividing the listed gross output values by the gross input values.

[4] For oil-fired boilers, a heating value of 140,000 Btu/gallon is used for boilers using light oil and 150,000 Btu/gallon is used for boilers using heavy oil.

excluded boiler models where $E_T \geq E_C$. The remaining boilers represent 59.4 percent of the boilers in the directory and include 1019 commercial boilers.

Table 8 shows a summary of the commercial boilers examined in the 2005 I=B=R ratings directory. The table shows that, for all of the small commercial boilers evaluated (gas and oil-fired), the average E_T is 80.9 percent and the average difference between combustion and thermal efficiency (ΔE) is 2.6 percent. For small gas-fired boilers, the average E_T is 79.7 percent and the average ΔE is 2.6 percent. For small oil-fired boilers, the average E_T is 82.3 percent and the average ΔE is 2.61 percent. Furthermore, Table 14 shows that among the small gas-fired commercial boilers that have E_C between 80 percent and 81 percent, the average E_T is 76.7 percent and the average ΔE is 3.6 percent. Among the small oil-fired commercial boilers that have E_C between 83 percent and 84 percent, the average E_T is 81.0 percent and the average ΔE is 2.5 percent. Finally, the 2005 I=B=R directory shows 105 minimally complying small gas-fired boilers (i.e., gas-fired boilers with E_C = 80.0 percent) and only one minimally complying small oil-fired boiler (i.e., oil-fired boilers with E_C = 83.0 percent) in Table 14. For small gas-fired boilers that minimally comply (E_C=80.0 percent), the average E_T is 76.8 percent and the average ΔE is 3.16 percent. Among the small, oil-fired boilers that minimally comply (E_C=83.0 percent), the E_T is 82.1 percent and the average ΔE is 0.9 percent.

Because some boilers have been excluded from the sample examined, few copper or stainless steel boilers of any size or fuel type are represented. Table 8 also shows the maximum, minimum, and standard deviation for the sample examined to show the range and variance in efficiencies.

Since the boilers examined represent only 59 percent of the boilers listed in the 2005 I=B=R ratings directory, it's important to determine whether the 59 percent examined are representative of the entire listing. To verify this, DOE performed a variance test on the E_C ratings for the boilers with E_T ratings as demonstrated by Ware.[27] The Department computed the mean (μ) and standard deviations (σ) for different commercial boilers categories. The results indicate that the dispersion among E_C values is somewhat tighter than a normal distribution and are also consistent with Ware.

Table 8. 2005 I=B=R Commercial Boiler Efficiency Summary[a]

Category	Gas			Oil			ALL BOILERS (Gas and Oil)		
	E_C (%)	E_T (%)	ΔE (%)	E_C (%)	E_T[b] (%)	ΔE (%)	E_C (%)	E_T (%)	ΔE (%)
Average (μ) Boilers of All Sizes	**81.83**	**79.55**	**2.28**	**84.59**	**82.32**	**2.27**	**83.14**	**80.86**	**2.28**
Maximum	97.10	96.40	5.10	93.30	92.90	6.90	97.10	96.40	6.90
Minimum	80.00	75.40	0.10	81.20	75.60	0.10	80.00	75.40	0.10
Standard Deviation (σ)	2.51	3.01	1.30	1.19	1.78	1.29	2.43	2.86	1.30
Count (n)	537	537	537	482	482	482	1019	1019	1019
Average (μ) ≥300 kBtu/h & <2,500 kBtu/h	**82.30**	**79.68**	**2.62**	**84.86**	**82.26**	**2.61**	**83.48**	**80.87**	**2.62**
Maximum	97.10	96.40	5.10	93.30	92.90	6.90	97.10	96.40	6.90
Minimum	80.00	75.40	0.10	81.20	75.60	0.10	80.00	75.40	0.10
Standard Deviation (σ)	3.20	3.79	1.36	1.34	1.93	1.31	2.83	3.33	1.34
Count (n)	288	288	288	246	246	246	534	534	534
Average (μ) Aluminum	85.90	85.00	0.90	93.30	92.90	0.40	89.60	88.95	0.65
Average (μ) Cast Iron	81.46	79.16	2.30	84.59	82.34	2.25	82.93	80.66	2.28
Average (μ) Copper	84.00	80.92	3.08	-	-	-	84.00	80.92	3.08
Average (μ) Steel	90.08	88.46	1.62	84.33	81.62	2.71	86.58	84.29	2.29
Average (μ) Stainless Steel	95.10	93.40	1.70	-	-	-	95.10	93.40	1.70

a. Model series starting with a "#" symbol in the I=B=R Ratings Directory are not included. Boiler models with $E_T \geq E_C$ are not included.
b. For light oil models, a nominal heating value of 140,000 Btu per gallon is used.
For heavy oil models, a nominal heating value of 150,000 Btu per gallon is used.

Table 9. 2005 I=B=R Commercial Boiler Minimally Complying Efficiency Summary[a]

Category	Gas				Oil			
	E_T for $80 \le E_C < 81$ (%)	ΔE for $80 \le E_C < 81$ (%)	E_T for $E_C = 80.0$ (%)	ΔE for $E_C = 80.0$ (%)	E_T^b for $83 \le E_C < 84$ (%)	ΔE for $83 \le E_C < 84$ (%)	E_T^b for $E_C = 83.0$ (%)	ΔE for $E_C = 83.0$ (%)
Average (μ) Boilers of All Sizes	**77.42**	**2.79**	**77.52**	**2.48**	**81.27**	**2.33**	**82.10**	**0.90**
Maximum	79.90	5.10	78.20	4.60	83.50	4.50	82.10	0.90
Minimum	75.40	0.90	75.40	1.80	79.20	0.10	82.10	0.90
Standard Deviation (σ)	1.34	1.34	0.93	0.93	1.15	1.23	0.00	0.00
Count (n)	156	156	105	105	196	196	1	1
Average (μ) ≥300 kBtu/h & <2,500 kBtu/h	**76.67**	**3.56**	**76.84**	**3.16**	**81.04**	**2.54**	**82.10**	**0.90**
Maximum	79.90	5.10	78.20	4.60	83.50	4.50	82.10	0.90
Minimum	75.40	0.90	75.40	1.80	79.20	0.10	82.10	0.90
Standard Deviation (σ)	1.33	1.35	1.05	1.05	1.13	1.18	0.00	0.00
Count (n)	78	78	47	47	72	72	1	1

a. Model series starting with a "#" symbol in the I=B=R Ratings Directory are not included. Boiler models with $E_T \ge E_C$ are not included.
b. For light oil models, a nominal heating value of 140,000 Btu per gallon is used.
For heavy oil models, a nominal heating value of 150,000 Btu per gallon is used.

As a result of the analyses based upon the GAMA directory data, it is evident that the average difference between E_C and E_T is on the order of approximately two to three percent as shown in Table 8 and Table 9, depending on the type of boiler. These values are lower than the five percent ΔE ASHRAE used in translating E_C efficiency levels in EPCA into E_T efficiency levels in Standard 90.1-1999 for small commercial boilers.

In addition, the above analysis indicates that the 0.200 quads of potential energy savings estimated in the screening analysis for adopting the Max NPV efficiency levels over the Standard 90.1-1999 efficiency levels for small gas-fired commercial boilers should be reduced. The Department calculated the 0.200 quads of potential energy savings as the difference in energy consumption between boilers with efficiencies at the Max NPV level of 78.7 percent E_T and the Standard 90.1-1999 efficiency level of 75 percent E_T (see Table 7). However, as shown above, the average E_T for small gas-fired commercial boilers is 79.7 percent in the 2005 I=B=R directory, which is greater than the Max NPV level estimated in the screening analysis. Therefore, if the average E_T values from the analysis above are used as the baseline in the calculation, there would be no potential energy savings because the average E_T values are already higher than the Max NPV efficiency levels.

CHAPTER 4. THREE-PHASE AIR-CONDITIONERS AND HEAT PUMPS <65,000 BTU/H

4.1 BACKGROUND

Three-phase central air-conditioners and central air-conditioning heat pumps (three-phase ACs) less than 65,000 Btu/h in cooling capacity are used in commercial applications and are physically the same as residential central air-conditioning units of the same sizes, except for certain electrical components (e.g., the compressor and fan motors, safety cutoffs). Residential central air-conditioning units have single-phase electrical components while the commercial versions have three-phase electrical components. The product classes being considered are air-cooled three-phase ACs less than 65,000 Btu/h that are either single-package or split-system.

Three-phase ACs and HPs fall within the small commercial package air-conditioning and heating equipment category, which is defined in EPCA as "air-cooled, water-cooled, evaporatively-cooled, or water source (not including ground water source) electrically operated, unitary central air conditioners and central air-conditioning heat pumps for commercial application which are rated below 135,000 Btu per hour (cooling capacity)." (42USC6311(8)) Energy efficiency levels for single-package three-phase ACs less than 65,000 Btu/h were set forth in EPCA at a seasonal energy efficiency rating (SEER) level of 9.7 for cooling and a heating seasonal performance factor (HSPF) level of 6.6 for heating (see Table 10). (42USC6313(a)(1)(B and E)) Energy efficiency levels for split system three-phase ACs less than 65,000 Btu/h were 10.0 SEER for cooling and 6.8 HSPF for heating. (42USC6313(a)(1)(A and D)) These efficiency levels are the same as those in Standard 90.1-1989. During the development of Standard 90.1-1999, ASHRAE explicitly chose not to revise standards for air-cooled three-phase ACs less than 65,000 Btu/h. This decision was based on the close relationship the design of these products has to residential, single-phase air-cooled air-conditioners and heat pumps less than 65,000 Btu/h, whose efficiency is regulated under Section 325 of EPCA. Subsequently, in the January 12, 2001, final rule (66 FR 3336), DOE stated that it would take no action on three-phase ACs since ASHRAE took no action. As a result, the EPCA energy efficiency levels for the three-phase ACs of 9.7 SEER for single-package units and 10 SEER for split systems remained in place. DOE completed its standards rulemaking to develop and set new efficiency standards for these single-phase products, and published a final rule in the Federal Register on May 23, 2002. 67 FR 36368. This rule sets efficiency standards for residential, single-phase air-cooled air conditioners and heat pumps at a SEER rating of 12.0 for both single-package and split-system heat pumps.

Table 10. Comparison of Energy Efficiency Standards for Three-Phase ACs

Category	Efficiency (SEER)					
	EPCA		Standard 90.1-1999		Addendum i to Standard 90.1-2001	
	Cooling (SEER)	Heating (HSPF)	Cooling (SEER)	Heating (HSPF)	Cooling (SEER)	Heating (HSPF)
3-Phase Single-Package AC	9.7	NA	9.7	NA	12.0	NA
3-Phase Single-Package HP	9.7	6.6	9.7	6.6	12.0	7.4
3-Phase Split-System AC	10.0	NA	10.0	NA	12.0	NA
3-Phase Split-System HP	10.0	6.8	10.0	6.8	12.0	7.4

Sources: EPCA, Standard 90.1-1999, and Standard 90.1-2001 Addendum i.

On January 22, 2001, the Department published a Final Rule setting a 13 SEER and 7.7 HSPF standard for residential central air conditioners and heat pumps. The Air-Conditioning and Refrigeration Institute (ARI) requested a judicial review of this rule by the US Court of Appeals for the 4th Circuit in Richmond, Virginia. Subsequently, DOE issued the May 23, 2002 rule, withdrawing the 13 SEER rule and enacting a 12 SEER and 7.4 HSPF standard. ARI supported this 12 SEER Rule.

In June of 2002, ARI proposed an addendum to the ASHRAE 90.1 committee during ASHRAE's annual summer meeting. The proposed addendum would adopt a 12 SEER rating for the three-phase commercial air-conditioning products and become effective in 2006 so as to be in effect in the building standard at the same time it becomes effective for similar single-phase residential products. In January of 2003 during ASHRAE's annual winter meeting, ASHRAE's technical committee voted on ARI's proposed addendum. The outcome of the voting was to accept the addendum to increase the energy efficiency of small three-phase air-conditioning units to match the 12 SEER efficiency adopted by DOE for single-phase residential air-conditioning units. Addendum i to Standard 90.1-2001 was approved by the ASHRAE Standards Committee on June 28, 2003, by the ASHRAE Board of Directors on July 3, 2003, and by the American National Standards Institute (ANSI) on August 6, 2003.

Opponents of the 12 SEER rule, namely the Natural Resources Defense Council, challenged the rule in a New York court on procedural grounds. On January 13, 2004, the US Court of Appeals for the 2nd Circuit in New York ruled that DOE, in enacting the 12 SEER standard, "failed to effect a valid amendment of the original standard (13 SEER) effective date, and as a consequence was thereafter prohibited from amending these standards downward." ARI withdrew its separate appeal of DOE's prior 13 SEER standard on January 17, 2004. On August 17, 2004, DOE published a technical amendment in the Federal Register to officially adopt the 13 SEER standard.

4.1 ENERGY SAVINGS

In the screening analysis, DOE estimated the national energy savings for various energy efficiency levels compared to the 10 SEER efficiency level in EPCA. It estimated savings for 11, 12, 13, and the max-tech 15 SEER. Since Standard 90.1-1999 analysis did not address three-phase air-conditioning units, the efficiency levels for these products remained at the EPCA 10 SEER level. The result is no energy savings in adopting Standard 90.1-1999 levels. However, with the Addendum i to Standard 90.1-1999, which raises the efficiency levels for three-phase ACs to a 12 SEER level, the national energy savings are estimated to be 2.174 quadrillion Btu (quads) as shown in Table 11.

Table 11. Potential Energy Savings for Three-Phase ACs

Category	EPCA 1992	90.1-1999 Relative to EPCA		Level 1 Relative to EPCA		Level 2 Relative to EPCA		Level 3 Relative to EPCA		Level 4 Relative to EPCA	
	SEER	SEER	Energy Savings (quads)	SEER	Energy Savings (quads)	SEER	Energy Savings (quads)	SEER	Energy Savings (quads)	SEER	Energy Savings (quads)
3-ph, Single-Package AC	9.7	9.7	0	11.0	0.871	12.0	1.413	13.0	1.871	15.0	2.604
3-ph, Single-Package HP	9.7	9.7	0	11.0	0.113	12.0	0.184	13.0	0.243	15.0	0.338
3-ph, Split-System AC	10.0	10.0	0	11.0	0.279	12.0	0.511	13.0	0.707	15.0	1.021
3-ph, Split-System HP	10.0	10.0	0	11.0	0.036	12.0	0.066	13.0	0.092	15.0	0.133
Total	**-**	**-**	**0.0**	**-**	**1.299**	**-**	**2.174**	**-**	**2.913**	**-**	**4.096**

Source: Screening Analysis (DOE 2000).[25]

The screening analysis also estimated that the Max NPV from energy savings (i.e., the lowest life-cycle cost) in the various efficiency levels analyzed occurs with a SEER level of 12.

4.2 ISSUES IMPACTING POTENTIAL ENERGY CONSERVATION STANDARDS

EPCA states that DOE must adopt amendments to ASHRAE Standard 90.1 unless it shows through clear and convincing evidence that a more stringent standard, that is technologically feasible and economically justified, would produce significant additional energy savings. EPCA bars DOE from adopting any standard that would increase the maximum allowable energy use or decrease the minimum required efficiency for a product. Therefore, DOE can either adopt the addendum to Standard 90.1-1999, increasing the energy efficiency level for three-phase air-conditioning units from a 10 SEER level established by EPCA to a 12 SEER level, or seek a higher energy efficiency level. The screening analysis estimated that adopting a 12 SEER efficiency level would achieve an energy savings of 2.174 quads. In addition, the 12 SEER efficiency level corresponds with energy savings that are estimated to yield the Max NPV (i.e., lowest life-cycle cost). On the other hand, if DOE were to seek a higher efficiency level, the estimated net present value would be lower. For example, if a 13 SEER efficiency level were adopted, energy savings are estimated to amount to only 0.739 quads relative to a 12 SEER level, and the life-cycle cost is estimated to be greater. The screening analysis estimated that the 12 SEER efficiency level for three-phase air-conditioning units has the lowest life-cycle cost.

Currently, the Department has been made aware that during ASHRAE's winter meeting of 2005, ASHRAE has completed public review of a proposed addendum to Standard 90.1 (Addendum f to Standard 90.1-2004) that would incorporate 13 SEER and 7.7 HSPF levels for three-phase ACs and HPs <65,000 Btu/h. Under ASHRAE's process, if the ASHRAE Standards Committee and ASHRAE Board approve this addendum during the 2006 ASHRAE winter meeting, it would then go to ANSI for approval, and its official adoption and publication would likely occur in the spring of 2006.

CHAPTER 5. SINGLE-PACKAGE VERTICAL AIR CONDIONERS AND HEAT PUMPS <65,000 BTU/H

5.1 BACKGROUND

SPVUs are a type of air-cooled small or large commercial package air-conditioning and heating equipment. They are factory assembled as a single-package having their major components arranged vertically, and they use single- or three-phase power. SPVUs are used primarily in schools, manufactured or modular buildings, telecommunication shelters, and portable buildings, and are subject to different duty cycles and operating hours than what is typically encountered in residential applications. SPVUs can be classified into several categories, including wall-mounted vertical package exterior units, cabinet units, wall-mounted vertical package interior units, large vertical interior units, and stacked vertical closet units.

The Department considered SPVUs in the November 24, 1999, residential central air-conditioners and heat pumps NOPR (64 FR 66306, Section IV.C.6). In the October 5, 2000, NOPR for Residential CACs (65 FR 59590, Section V.J.1), DOE determined that SPVUs were commercial products not subject to residential efficiency standards. Subsequently, DOE included these products as part of their evaluation of commercial HVAC equipment under the ASHRAE products rulemaking. On July 30, 2002, ASHRAE adopted Addendum d to Standard 90.1-2001, which contains energy conservation standards and test procedures for SPVUs.

In a July 25, 2003, letter from DOE to ARI, DOE rejected the standards and test procedure (ARI 390-2001) in Addendum d and stated reasons for this decision. ARI replied to this letter on November 4, 2003, proposing changes and additions to ARI 390 and Addendum d to address the Department's complaints. On March 16, 2004, the Department responded to ARI's proposed changes and additions, accepting all of the changes to ARI 390 and some of the changes to Addendum d, and stated other concerns that must be addressed before DOE would adopt Addendum d. ARI addressed the Department's remaining concerns in a May 12, 2004, letter. On May 24, 2004, ARI submitted to ASHRAE a "proposed change to ASHRAE standard under continuous maintenance" that included the changes discussed between ARI and DOE. ASHRAE accepted the continuous-maintenance proposal, and largely incorporated its contents into proposed Addendum b to Standard 90.1-2004. At this point, ASHRAE has completed its public review process of Addendum b and is in the final stages of considering whether to approve the addendum.

In Addendum b, ARI redefined both SPVACs and SPVHPs as encased air-cooled small or large commercial package air-conditioning and heating equipment. Additionally, it created SPVU categories corresponding to the equipment categories in EPCA. As a result of revisions made to ARI Standard 390, any standards and test procedures ASHRAE prescribed for SPVU equipment would apply to equipment covered by EPCA, and not overlap with EPCA definitions of PTACs and PTHPs.

Even though Addendum b contained recommended efficiency levels for SPVUs ≥65,000 Btu/h, EPACT 2005 supercedes ASHRAE Addendum b for these products. The signing of EPACT 2005 by the President divided SPVUs into two categories: those products <65,000 Btu/h and those products ≥65,000 Btu/h to <760,000 Btu/h. The Department will continue its evaluation of products <65,000 Btu/h, which are the subject of this notice. However, the SPVUs ≥65,000 Btu/h to <760,000 Btu/h are covered under the standards specified by EPACT 2005 and are not included in this TSD.

The energy descriptor used by ARI for SPVUs is EER/COP, which is a significant change from the SEER/HSPF descriptor used to rate similarly designed residential three-phase central air conditioners and heat pumps <65,000 Btu/h. The use of the EER/COP descriptor may be more appropriate for SPVUs because the intended use is different than that of residential central air conditioners. SPVUs, as mentioned above, are subject to different duty cycles and operating hours than what is typically encountered in residential applications.

5.2 ENERGY SAVINGS

The Department estimates the potential energy savings for going beyond ASHRAE efficiency levels for SPVU products <65,000 Btu/h to be 0.137 quads of primary energy. The methodology and data used to make the estimate are described below.

5.2.1 SPVU Shipments

ARI does not currently track shipments of SPVU products separately from other small package unitary products. At the request of DOE in 2003, ARI consulted with manufacturers of SPVU products and provided shipment data to DOE under confidentiality. Such an agreement was deemed necessary given the small number of manufacturers of these products. ARI provided actual shipment data for the period from 1995 to 2001, and provided estimates of shipments from 2001 to 2005. For the purpose of this rulemaking, DOE assumed ARI's estimate of product shipments for 2005 to be adequate for an initial energy savings estimate. The estimated product shipments are shown in Table 12 below.

Table 12. Product Shipments

Product Category	2005 Shipments*
SPVAC < 65,000 Btu/h, single-phase	31,976
SPVHP < 65,000 Btu/h, single-phase	13,125
SPVAC < 65,000 Btu/h, three-phase	14,301
SPVHP < 65,000 Btu/h, three-phase	6129
Total <65,000 Btu/h	**65,531**

* ARI Estimate

The Department estimated the growth rate in shipments for SPVU products based on the data made available by ARI to DOE for commercial unitary AC products 65,000

Btu/h to 240,000 Btu/h for DOE's commercial unitary air conditioners and heat pumps (CUAC) rulemaking. During the period from 2010 to 2037, the growth rate in the base case for the CUAC products averaged 2.18 percent. DOE assumed the same average growth rate for its analysis of SPVUs. DOE calculated savings from adopting efficiency levels above ASHRAE's separate efficiency levels for both single-phase and three-phase products.

5.2.2 Equipment Size Analyzed

According to ARI data provided to the Department, the most common SPVU size shipped in the <65,000 Btu/h size category is a nominal 3-ton capacity unit (36,000 Btu/h). Actual SPVU products range from nominal sizes of 3/4 tons (3,000 Btu/h) to 5 tons (60,000 Btu/h) in capacity. This analysis assumed that total shipped capacity can be reasonably estimated by multiplying the most common size product (3 tons or 36,000 Btu/h) by the total shipments.

5.2.3 Time Frame

According to EPCA, the minimum time frame for DOE to promulgate a rule that increases the efficiency for small or large package commercial air-conditioning equipment (including SPVU products) above what is in Standard 90.1 is four years. Hence, the earliest possible date for the Department to develop a minimum efficiency standard above Standard 90.1-2004 Addendum b levels (assuming publication in 2005) would be 2009. However, the Clean Air Act Amendments of 1990 require manufacturers to phase out the use of hydrofluorocarbon (HFC) and hydrochlorofluorocarbon (HCFC) refrigerants by January 1, 2010. Given manufacturer concerns with adoption of a new refrigerant, a more practical effective date for the new standards would be 2010. Because the minimum efficiency levels promulgated under ASHRAE are very close to the minimum efficiency levels under EPCA for this analysis, DOE calculated only the energy savings from going beyond ASHRAE level starting in 2010. It used a 28-year timeframe from 2010 to 2037 as the basis for the energy savings analysis.

5.2.4 Product Life

The Department estimated the product lifetime for SPVUs to be 15 years based on ASHRAE's estimate of the lifetime for CUAC products.

5.2.5 Efficiency Levels Analyzed

The base case efficiency levels for this analysis are assumed to be those in Standard 90.1-2004 Addendum b. These levels are 9.0 EER for SPVACs and SPVHPs <65,000 Btu/h, and 3.0 COP for SPVHP products <65,000 Btu.

The Department's estimate of maximum potential energy savings for SPVU products <65,000 Btu/h is based on the assumption that all products could be designed to reach the maximum efficiency levels currently available on the market. Product data provided by ARI suggest that maximum efficiency levels are currently at 10.9 EER for SPVHP products and 10.7 EER for SPVAC products <65,000 Btu/h. Given that there seems to be no evidence that SPVAC products could not be designed to be as efficient as SPVHP products, the maximum efficiency used in this analysis is 10.9 EER.

The Department did not analyze energy savings potential for heating. However, the highest heating efficiency currently on the market for SPVHP products <65,000 Btu/h is 3.4 COP. This level, however, corresponded to products with cooling efficiencies of 10.5 EER. The SPVHP products with cooling efficiencies of 10.9 EER have heating efficiencies of 3.1 COP.

5.2.6 Unit Energy Savings

The Department developed an estimate of unit energy savings for SPVU products based on an analysis of energy consumption for commercial unitary air conditioner products used in education building applications. The energy and end-use load characterization analysis for the Commercial Unitary Air Conditioners developed energy consumption estimates for a sample of 1033 commercial buildings where 99 of those buildings were education buildings. Because of high occupancy density, the cooling load on an education building is largely a function of the heat gains from lights, occupants, and ventilation air. Because similar levels of each would be expected in a portable classroom-type application, DOE felt that the cooling energy consumption estimates from this building set would be reasonably reflective of cooling load estimates for portable classrooms. In addition, scheduled hours of use are expected to be similar.

Two primary sources of energy consumption exist in a package air conditioner; the compressor/condenser energy consumption (including condenser fan) that operates to provide cooling (or in the case of the heat pump, reverse cycle heating), and the supply-air blower. Because, in a commercial application, the supply blower generally runs continually during occupied hours to provide for ventilation in the building, its energy consumption during the course of the year can be large relative to the compressor/condenser energy consumption.

The relative operating hours of fan and condenser in an SPVU product are expected to be similar to that of a commercial unitary air conditioner used in the same application. However, on a horsepower-per-ton-cooling-capacity basis, the fan in an SPVU is small relative to the fan in a larger single-package rooftop air conditioner. While the fan in the rooftop unit can be expected to provide for up to two inches or more external static pressure, the maximum external static pressures listed for SPVU used in mobile classrooms is typically no more that 0.5 inches. A supply fan for a 7.5-ton rooftop air conditioner would use a 1- to 3-horsepower (hp) motor depending on product design. A common product would use a 2-hp motor for low-to-moderate external static pressures, with an option for a larger motor for higher external static pressure applications. By contrast, a typical size supply fan motor on a standard efficiency 3-ton SPVU is an one-third horsepower blower motor directly connected to two small blowers. The Department estimated the fan power consumption for a baseline SPVU product assuming an one-third horsepower blower and a 65 percent motor efficiency. This corresponds to a power draw of 0.379 kilowatts (kW).

The fan power consumption estimate for an education building used in the CUAC rulemaking for a baseline 8.9 EER 7.5-ton air conditioner with a gas heating section was 2.41 kW at an external static pressure of 1.25 inches. This corresponds to 0.3212 kW/ton, or a 0.964 kW fan power consumption for a 3-ton product. Because this is well over the expected power draw from an SPVU motor, DOE multiplied the expected supply fan energy consumption from the CUAC analysis by the ratio of the expected SPVU blower power draw (0.379 kW) to the supply fan power draw used in the CUAC analysis (0.964 kW). This ratio is calculated to be 0.393.

After accounting for the change in fan energy consumption, DOE estimated the resulting total energy consumption for SPVUs used in mobile classroom education buildings in terms of annual kWh/ton at each EER level analyzed in the Commercial Unitary AC analysis (Table 18). Because the estimate of shipments corresponds to the tonnage assuming a baseline (no new standard) scenario, the tonnage used to calculate the kWh/ton ratio is the original tonnage estimate for all education buildings based on an assumed baseline 9.0 EER product. In addition, DOE estimated energy consumption for intermediate levels of 9.0 and 10.9 EER through interpolation of energy consumption between actual levels simulated.

Table 13. Annual Energy Consumption Estimates for SPVU, Cooling + Fan

EER	Annual Energy Consumption for Education Buildings, CUAC Analysis (KWh/ton/yr)	Annual Energy Consumption for Education Buildings, SPVU Analysis (KWh/ton/yr)
8.5	2270	1537
8.9	2186	1470
9.0	2166	1454
9.5	2074	1379
10.0	1991	1313
10.1	1975	1301
10.5	1916	1254
10.8	1874	1222
10.9	1861	1211
11.0	1848	1201
11.5	1786	1152
11.8	1752	1126
12.0	1730	1109

5.2.7 Calculation of Energy Consumption by Standard Level

The Department based the calculation of national energy consumption for a standard level on the annual energy consumption for all the products shipped in that year for each year being studied. This is simply a multiplication of total shipments, assumed average system size (tons), and the appropriate annual energy consumption (in kWh/ton) for that standard level. For this analysis, DOE calculated only cooling and supply fan energy consumption.

To estimate accumulated energy savings over the life of the study period, DOE calculated the total energy use for all the products shipped since the beginning of the study period (and still in operation). Products that have exceeded their expected service life of 15 years for any year of the study are removed from service during that year, and thus have no energy consumption associated with them.

The resulting cooling and fan energy consumption estimates for all SPVAC and SPVHP for the study period from 2010 to 2037 are shown in Table 14 in terms of total kWh electric consumption and total primary energy consumption (quads).

Table 14. National Energy Consumption Estimate (Cooling and Supply Fan), 2010 to 2037

Product Category	**9.0 EER**		**10.9 EER**	
	Electric (gWh)	**Primary (Quads)**	**Electric (gWh)**	**Primary (Quads)**
SPVAC <65,000 Btu/h, 1 phase	64,625	0.488	54,219	0.410
SPVHP <65,000 Btu/h, 1 phase	26,526	0.200	22,255	0.168
SPVAC <65,000 Btu/h, 3 phase	28,903	0.218	24,249	0.183
SPVHP <65,000 Btu/h, 3 phase	12,387	0.094	10,392	0.079
Total SPVU <65,000 Btu/h	**132,441**	**1.001**	**111,116**	**0.840**
Savings			**21,325**	**0.161**

National energy savings in going from 9.0 EER to a 10.9 EER product are estimated to be 0.161 quads for cooling and fan energy consumption. At this time, DOE has not made a separate detailed calculation for the potential energy savings for improving the heating COP for SPVHP products.

The Department expects the additional potential energy savings for heat pumps would be unlikely to increase the energy savings estimate shown above by more than 20 percent, due to the relatively small market volume for SPVHP equipment (31 percent of total shipments of SPVUs) and smaller potential improvement in heating COP compared with cooling EER.

5.3 ISSUES IMPACTING POTENTIAL ENERGY CONSERVATION STANDARDS

5.3.1 SPVU Test Procedures and Standards

In 2002, ASHRAE published Addendum d to Standard 90.1-2001. The intent of Addendum d was to establish SPVACs and SPVHPs or, collectively, SPVUs, as a new product class of air-conditioning and heating equipment as well as to establish test procedures and standards for these products. Under EPCA, the publication of the addendum triggered a review at the DOE to determine if the amended Standard 90.1 could be adopted as a Federal standard. DOE's examination of Addendum d revealed some deficiencies and other concerns with the test procedures (ARI Standard 390-2001) as well as with the minimum efficiency standards, which were inconsistent with current Federal regulations.

In May of 2004, ARI submitted a continuous-maintenance proposal to ASHRAE, which corrected the deficiencies and addressed most of the remaining concerns identified by DOE. This proposal was presented in the June 2004 ASHRAE annual meeting and was cleared for public review. In November of 2004, ASHRAE announced a 45-day public review period regarding the SPVU modifications contained in the ARI proposal, and a new addendum was issued (Addendum b to Standard 90.1-2004). Addendum b included the following changes:

1. Test procedure references which apply to SPVACs and SPVHPs were changed from ARI 210/240 and ARI 340/360 to ARI Standard 390-2003.
2. Definitions of SPVAC and SPVHP were added to Standard 90.1-2004.
3. Modifications to the efficiencies for SPVAC and SPVHP products were made as follows:
   a) SPVAC <65,000 Btu/h - EER was changed from 8.6 to 9.0
   b) SPVHP <65,000 Btu/h - EER was changed from 8.6 to 9.0
   c) COP was changed from 2.7 to 3.0.
4. The table was reformatted to reflect a different organization structure in Standard 90.1-2004.

5.3.1.1 Statutory Criteria for Amended Test Procedures

According to EPCA, if an industry test procedure is amended, DOE must amend the DOE test procedure to be consistent with the industry test procedure or determine by rule that doing so does not meet the statutory criteria for Federal test procedures. (42 U.S.C. 6314 (a)(4)(b))

The statutory criteria for Federal test procedures require that a test procedure be reasonably designed to produce test results which reflect energy efficiency, energy use, and estimated operating costs of a type of industrial equipment (or class thereof) during a representative average use cycle (as determined by the Secretary), and shall not be unduly burdensome to conduct. (42 U.S.C. 6314 (a)(2)) In other words, the Department may not adopt changes in an industry test procedure prescribed by ASHRAE Standard 90.1 if the amended industry test procedure does not provide results that are accurate and repeatable, and is unduly burdensome to conduct.

Therefore, the Department must determine whether the new test procedures in ARI 390-2003 for SPVUs meet the statutory requirements that they be reasonably designed to assess the products and produce accurate results, and not be unduly burdensome to conduct.

5.3.1.2 Evaluation

Under EPCA, the heating efficiency metric for commercial 3-phase heat pumps <65,000 Btu/h is the HSPF. For commercial single-phase heat pumps <65,000 Btu/h, EPCA does not prescribe a standard, and therefore does not have a heating efficiency metric defined. For all heat pumps ≥65,000 and <135,000 Btu/h, EPCA uses COP as the heating efficiency metric.

Under Addendum b, the proposed heating efficiency metric for SPVHPs is COP. Therefore, under the proposed changes in Addendum b, the heating efficiency metric is being changed for three-phase SPVHPs <65,000 Btu/h.

The HSPF test procedure does not measure the "backup" electric resistance heat needed under all conditions. Instead it calculates the electric resistance heat that would be needed because:

(1) the heat pump capacity at those temperature cannot meet the estimated building load through the reverse-cycle heating (based on steady-state operation of the heat pump for outdoor air above 45 F or below 17 F);
(2) the heat pump capacity at those temperature cannot meet the estimated building load through the reverse cycle heating (through use of the defrost cycle operation of the heat pump); or
(3) the heat pump reverse cycle heating has been deliberately controlled to be off based on a certain temperature switch (typically a low temperature controller).

In the case of (1), the amount of electric resistance heat is a function of the heating capacity of the reverse-cycle unit. If the heating capacity of the unit as a function of temperature is the same under COP or HSPF standard, the choice of either standard won't affect the amount of backup resistance for this purpose. This may be the primary source of electric resistance backup in these products.

In the case of (2) however, there is an issue regarding the defrost controller. The defrost controller takes heat from the building to defrost the compressor, while at the same time running the backup electric resistance elements to provide heat to the building. Different strategies for defrost mechanisms and defrost control may result in varying amounts of overall reverse-cycle heating capacity during periods with outdoor air between 17 and 47 F, and thus different amounts of backup heat.

In the case of (3), there is a potential issue because a manufacturer could decide to use electric resistance heat in place of the compression heat by deliberately forcing the compressor off. Typically this might be done to prevent damage to the compressor at some low temperature if, for instance, it was so cold outside as to prevent evaporation of the refrigerant. However, in this instance there would not be any capacity either and 1) above would apply. The HSPF test procedure takes this into account in calculating the amount of backup heat. It is likely that, in most normal designs, there would be little differential impact on system electric heat from this reason in the case of HSPF or COP standards.

Electric heat may also be provided through a fourth option (provided for in the DOE test procedure) which is the simultaneous use of reverse-cycle heating and electric resistance heat, even when the reverse cycle heating can meet the load. This can be done to raise the temperature of the heating air supply for comfort reasons. ASHRAE has referred to this within 90.1-2001, and allows it as long as the equipment meets the HSPF as required since the HSPF test procedure would include this use of resistance heat in the HSPF rating. However, it is not clear where in the ARI 390 test procedure this would be accounted for. The amount of electric resistance heat used for this may not be adequately accounted for in a high-temperature COP test alone and presents a potential loophole.

The proposed COP metric alone cannot guarantee maintenance of the efficiency provided by the HSPF rating, since it does not account for the electric resistance backup that might occur in (2) or (3), or that might be accounted for in (4).

5.3.1.3 Statutory Criteria for Amended Standards

According to EPCA, the Department is required to further investigate any standards that could represent a lowering of the existing efficiency levels. Moreover, the Department decided to further investigate whether the amended standards represented a lowering of the EPCA standards when the existing metric of HPSF was changed in Addendum b to COP to measure the heating efficiency of the unit. EPCA specifically states that any amended standard be rejected if it represents a lowering of the standard in accordance with 42USC6313(a)(6)(B)(ii).

According to EPCA, certain provisions are established for amended test procedures and energy conservation standards for consumer products. There are no equivalent requirements for commercial equipment, such as SPVUs. However, there is nothing preventing the methodology provided in EPCA from being applied to commercial equipment. The provisions set forth for consumer products state that, if an industry test procedure is amended such that the test procedure alters the measured efficiency, DOE must amend the DOE standard according to requirements set forth in EPCA. (42USC6293 (e)(2))

Therefore, to ensure that the Department is in full compliance with EPCA, the Department examined the relationship between HSPF and heating COP analytically to determine whether the proposed standard levels in Addendum b represent a reduction of efficiency levels.

5.3.1.4 Evaluation

In order for the Department to determine whether the ARI standard levels proposed in Addendum b were reductions to the existing EPCA standard levels, DOE conducted a comparative analytical study between each of the efficiency metrics. Table 15 shows the efficiency standard levels in EPCA, Standard 90.1-1999, and the proposed Addendum b.

Table 15. Existing and Proposed Efficiency Standard Levels

	Capacity (kBtu/h)	EPCA	Addendum d to 90.1-2001	Addendum b to 90.1-2004
SPVAC (Cooling)	Single-Phase	None	None	9.0 EER
	Three-Phase	9.7 SEER	8.9 EER	9.0 EER
SPVHP (Cooling)	Single-Phase	None	None	9.0 EER
	Three-Phase	9.7 SEER	8.9 EER	9.0 EER
SPVHP (Heating)	Single-Phase	None	None	3.0 COP
	Three-Phase	6.6 HSPF	2.7 COP	3.0 COP

5.3.1.5 Analysis of SPVAC Efficiencies – Cooling

Figure 5 shows a summary of the ARI market data for SPVAC cooling efficiencies with the bars representing the total number of product models identified with a given SEER and the vertical lines representing the range and numeric average of EERs for those products.

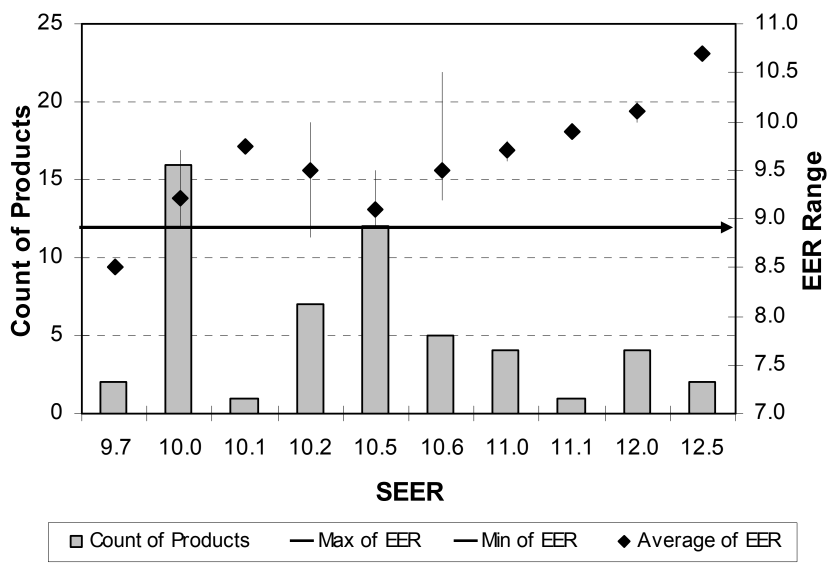

Figure 5: SPVAC <65,000 Btu/h Market Data by EER Level

Of the 54 models ARI identified, only 2 were exactly at the current minimum standard level of 9.7 SEER. These models are probably anomalous because both of these models, with an EER of 8.5 in the ARI data, are from the same manufacturer and are of the SPVU type that is designed as a through-the-wall PTAC replacement. One of these models may actually be a heat pump, while the other is a true air conditioner. In both cases, the manufacturer's product literature reviewed actually rated these products as an 8.7 EER, not an 8.5 EER.

Considering the rest of the market data, there were also 16 products with SEER of 10.0. These products have corresponding EERs ranging from 8.9 to 9.7, with an average of 9.21. Using a differential approach, the difference between the market minimum 10 SEER and the EPCA minimum 9.7 SEER is 0.3 points. Applying the 0.3 point differential to the 9.21 EER average gives an 8.91 EER.

Using a ratio approach (the ratio of the 9.7 SEER EPCA minimum to the 10.0 SEER market baseline), the efficiency would be established at 97 percent of the market baseline in terms of SEER. By applying the 97 percent ratio to the average market baseline in terms of EER (9.21 EER), 97 percent of that value would give an EER of 8.93. The use of a ratio is shown here because it becomes important in the translation between heat pump heating COPs below.

5.3.1.6 Analysis of SPVHP Efficiencies – Cooling

The ARI market data for SPVHPs is shown graphically in Figure 6.

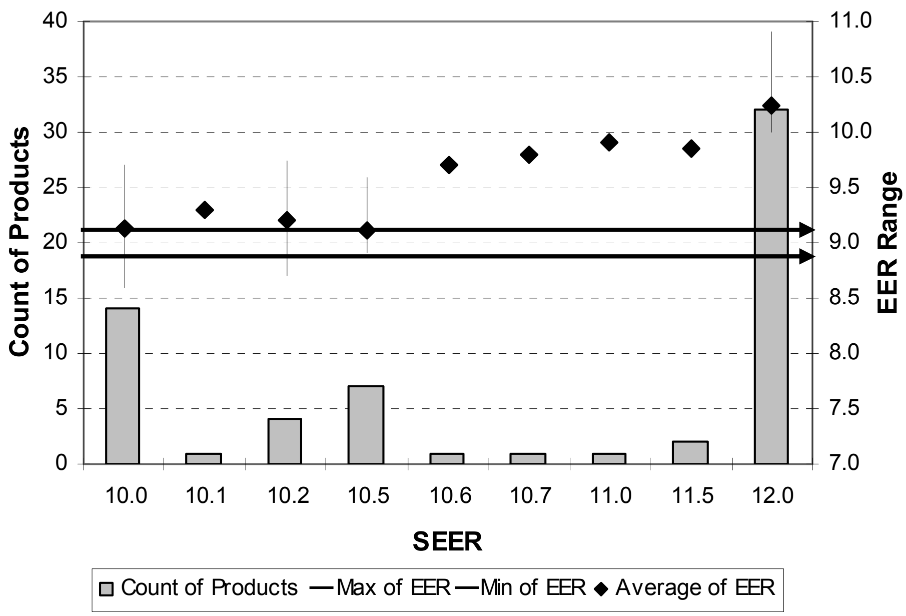

Figure 6: SPVHP <65,000 Btu/h Market Data by EER level

Figure 6 indicates that there were no products at the current DOE minimum of 9.7 SEER. However, there were 14 models identified at a 10 SEER level. The range of EERs for those products was from 8.6 to 9.7 with an average of 9.13. When applying the differential approach (a 0.3 differential between the market minimum of 10 SEER and the EPCA minimum of 9.7 SEER), subtracting a 0.3 point differential from the 9.13 EER average gives 8.83 EER.

5.3.1.7 Analysis of SPVHP Efficiencies – Heating

The ARI market data for SPVHP <65,000 Btu/h products are shown graphically in Figure 7.

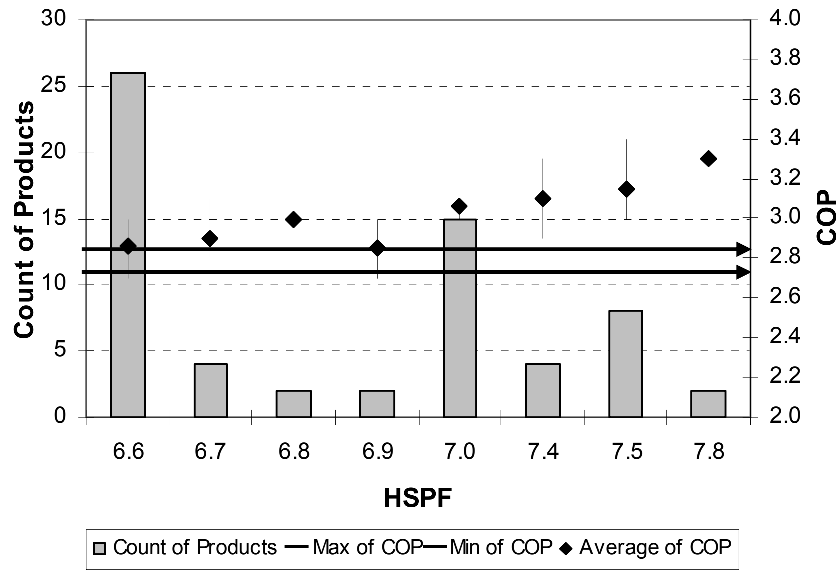

Figure 7: SPVHP <65,000 Btu/h Market Data by HSPF Level

Of the 63 products identified by ARI, there are 26 models at the minimum HSPF of 6.6 as established by EPCA. The minimum COP for those products was 2.7. The average COP was 2.86 for that group, with a range from 2.7 COP to 3.0 COP. For products with an HSPF of 6.6, the distribution of COP is shown in Table 21 below.

Table 16. Distribution of COP for SPVHP Products with 6.6 HSPF

COP	Count of Products
2.7	5
2.8	6
2.9	10
3.0	5

Extending the range of low HSPF products considered to cover products with HSPF values between 6.6 and 6.8, inclusive, adds only 6 more products (total 32), and the average HSPF goes to 6.63, and the average COP goes to 2.87. Because the majority of the market in this range is at the EPCA minimum value, it may not be appropriate to use a larger range of HSPF values. However, even if the Department did so, because of the scale of the values of HSPF compared with COP, it would be inappropriate to simply use an average differential between the HSPF and COP metrics in calculating what would be an appropriate market COP minimum. Using a ratio between the two metrics is however appropriate. The ratio of the market average COP for this product range to the market average HSPF is 0.4335. Applying this ratio to an HSPF of 6.6 gives a corresponding COP of 2.861.

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APPENDICES

Appendix A. PTAC and PTHP Energy Savings Analyses

Appendix A-1 Revised Cooling Mode Energy Savings Analysis

A-1.1 Background

The purpose of this work is to evaluate the energy savings potential for PTAC and PTHP products. A method of evaluating commercial heat pumps was designed for use in performing the screening analysis. The current analysis assesses the energy savings potential for these products based on an updated version of the screening analysis methodology. This analysis is based on the assumption that product efficiency levels that meet the current maximum efficiencies on the market represent the highest efficiency levels that DOE could possibly require.

A-1.2 Equipment Efficiencies

Market maximum efficiency levels used in the analysis were determined using the April 2002 directory of PTACs and PTHPs.[2,3] Table A - 1 shows the highest efficiency products listed in the ARI directory. Product selections were made based on existing products that can provide the efficiency levels indicated for the sizes analyzed, which are predominantly industry standard size (42" x 16") products.

Table A - 1: Market Maximum Efficiency Levels for PTACs and PTHPs

Capacity Range (Btu/h)	Size Analyzed (Btu/h)	EER	
		PTAC	PTHP
<7,000	6,000	11.8	12.1
7,000-10,000	8,500	12.0	11.5
10,000-13,000	11,500	11.0	11.0
>13,000	14,000	9.6	10.0

Sources: April 2002 ARI PTAC Directory (ARI 2002a).[2]
April 2002 ARI PTHP Directory (ARI 2002b).[3]

A-1.3 Shipments

A-1.3.1 Shipments by Year

Historical data for PTAC and PTHP shipments are available from the Current Industrial Reports published by the U.S. Census Bureau (Census) (Census 2000) and are summarized for 1996 to 2000 in Table A - 2 below. However, analysis of the shipment data from later years suggests some inconsistency between ARI estimated shipments and shipments provided by the Census Bureau. For example, the Current Industrial Report's shipments for the year 2000 are less than 50% of the reported shipments from ARI. Estimated ARI shipments for 2000 are 430,000 units and for 2001, 387,000 units.[1] In addition, the Census estimated shipments for 1999 (347,338 units reported) are below the 468,000 unit estimate that ARI provided to DOE in 1999 for the Screening Analysis. Also, in 1994, ARI provided shipment estimates for 1993 equal to 127,000 PTAC units and 99,000 PTHP units. These estimates were reported for units greater than 7,000 Btu/h in capacity only. The Census estimates for 1993 were 79,433 PTAC units and 57,225 PTHP units. It appears that the Census shipment estimates consistently do not reflect the ARI's estimate of product shipments. The reason for that has not been ascertained. Average ARI shipment estimates for 1999-2001 have been used as the base shipments for this study. An average 1% per year growth rate is assumed.

Based on the historical ratio of PTHP to PTAC products, in both Census and ARI estimates it is believed that approximately 55% of products are PTACs and 45% are PTHPs.

Table A - 2: Reported Shipments of PTACs and PTHPs

Year	PTAC (units)	PTHP (units)	Total (units)
2001 ARI	212,850	174,150	387,000
2000 ARI (estimated)	236,500	193,500	430,000
2000 ARI	252,000	216,000	468,000
2000 (Census)	105,360	96,349	201,709
1999 (Census)	191,564	155,774	347,338
1998 (Census)	185,745	156,132	341,877
1997 (Census)	168,084	130,736	298,820
1996 (Census)	151,089	112,549	263,638
Average (1999-2001), ARI Estimate	233,783	194,550	428,333

Sources: Current Industrial Reports – Refrigeration and Heating Equipment (Census 2000).

A-1.3.2 Shipments by Capacity

Shipments by capacity are based on estimates provided by ARI for the DOE Screening Analysis. The breakdown by size category is shown in Table A - 3.

Table A - 3: Shipments for PTACs and PTHPs by Capacity

Capacity Range (Btu/h)	Shipments (%)	
	PTAC	PTHP
<7,000	7.1	7.4
7,000-10,000	36.9	41.2
10,000-13,000	38.5	34.3
>13,000	17.5	17.1

Source: Screening Analysis (DOE 2000).

A-1.3.3 Shipments by Physical Dimension

There is a market for PTAC and PTHP products based on sleeve sizes that are no longer considered industry standards. The current industry standard size is 42"x16". For products designed for sleeves smaller that 42"x16", a separate set of lower EER and COP curves was developed by ASHRAE. This was done to provide attainable efficiency levels for these smaller products, since it would generally not be considered cost-effective to resize the building opening to accept larger sleeve size products. According to K. Amrane from ARI, only two ARI manufacturers currently make these non-standard products - EMI/RetroAire and McQuay (personal communication, June 14, 2002). However there are a number of smaller manufacturers (e.g., Islandaire) who have specialized in this market. Because of antitrust concerns, ARI did not gather and provide separate estimated shipments for these smaller sleeve size products since they would cover only two manufacturers. However, the Center for Energy and Environment (CEE) estimates PTAC shipments of major manufacturers (CEE 1999). Table A - 4 summarizes this information. Estimates are based on Minneapolis product representative surveys and may differ from national rankings.

Table A - 4: PTAC and PTHP Regional Market Ranks by Equipment Type

Brand	PTAC	PTHP
Amana	Large	Large
Zoneline	Large	Large
Carrier	Large	Small
Friedrich	Medium	Large
McQuay	Small	Large
Trane	Medium	Medium
Climatemaster**	Unknown	Unknown

Source: A Practical Guide to Commercial A/C Rebates for Municipal Utilities (CEE 1999).
Note: Within each size category (i.e. Large, Medium, and Small), manufactures are listed alphabetically.
* Suppliers were categorized as "large," "medium," or "small" based on representatives estimates of regional market shares (normalized to 100%) as follows: large supplier typically has at least 15% of regional market share, medium 6-14%, and small 5% or less.
** The survey with the ClimateMaster representative could not be completed. ClimateMaster's market share is believed to be very small based on the reports of other PTAC/PTHP representatives.

Estimates for the product shipments which would fall in the lower "non-industry standard" size classes are highly speculative. However, given the market share of McQuay at roughly 15% for PTHP products and 5% or less for PTAC products and assuming that sales by EMI/Retroaire, Islandaire and other non-standard equipment manufacturers are very small, one can estimate the size of the non-standard market at approximately 10-15% of the total market. It is recognized that this is a very rough estimate. For the purposes of this analysis, DOE assumes that 15% of the total packaged terminal product shipments are in the non-industry standard size market and 85% are in the industry standard size 42"x16" market.

A-1.3.4 Total Estimated Shipments

Based on the information presented above, estimated shipments that are used in the revised cooling mode energy savings analysis are presented in Table A - 5 below by equipment type, capacity range, and physical dimensions.

Table A - 5: Estimated PTAC and PTHP Shipments

Capacity Range (Btu/h)	Estimated Shipments ≥42”x16”		Estimated Shipments <42”x16”	
	PTAC	PTHP	PTAC	PTHP
<7,000	14,109	12,237	2,490	2,160
7,000-10,000	73,326	68,131	12,940	12,023
10,000-13,000	76,506	56,721	13,501	10,010
>13,000	34,775	28,278	6,137	4,990
Total Shipments	**198,716**	**165,368**	**35,068**	**29,183**

A-1.3.5 Shipments by Building Application

The estimated maximum savings potential for PTAC and PTHP products is based on an update to the DOE Screening Analysis for these commercial products. The updated methodology modified the estimates for building shares using PTAC/PTHP equipment to reflect use of packaged AC equipment and heat pumps in lodging facilities. This is in response to comments on the 2000 “Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment” that loads more representative of the PTAC/PTHP application be used. The impact of modifying the shipment estimates for this work is to modify the full-load equivalent operating hours (FLEOH) to reflect those for lodging facilities. It is noted that packaged terminal products are used primarily in motel/hotel applications, but there is a significant fraction are found in healthcare and assisted living facilities. Estimates of usage by three major manufacturers are shown below.

Table A - 6: Shipments by Building Category

Manufacturer	Application		
	Hotel/Motel	Assisted Living/Healthcare	Office/Residential/Misc.
AMANA/GOODMAN	50%	35%	15%
Carrier	65%	25%	10%
Trane	95%	<5%	<5%

Source: “PTACS Are Not Just For Hotels and Motels”, ACH&R News, June 10, 2002.[1]

A-1.4 New Versus Replacement Equipment Market

The tools developed for the analysis provide for estimates of shipments to new and to replacement markets. The non-standard size products which are allowed lower efficiency levels by ASHRAE Standard 90.1-1999 must be explicitly labeled for use only as replacement products in existing buildings and therefore 100% of the shipments are assumed to go to replacement applications. For 42"x16" products, it is estimated that approximately 80% of the market will be for replacement applications and 20% for new building applications within a given year.

A-1.5 Energy Savings Potential for Larger Sleeve Size PTACs and PTHPs

Table A - 7 shows energy and carbon savings estimates developed for packaged terminal products for new standards. The savings estimates are relative to the current standard (EPCA 1992) levels and are cumulative savings through 2030. It is assumed that currently, it would not be possible for DOE to complete the rulemaking process for establishing a higher efficiency standard prior to 2004, which would result in a final standard in 2008 (scenario 4). It is assumed that simple adoption of the ASHRAE standard at this time (2003) would allow for a manufacturing standard at those levels to be in place by 2005 (scenario 2).

The analysis suggests that for these 42"x16" products, the maximum energy savings potential in proceeding to a final rule with a standard at a level higher than Standard 90.1-1999 versus adoption of Standard 90.1-1999 levels in 2005 is approximately 0.05 quads through 2030. Again it is assumed that these industry standard products cover approximately 85% of the existing market. The adoption date strongly influences the energy savings potential. If a final rule could be established at market maximum efficiency levels by 2005, the energy savings potential would be approximately 0.135 quads.

Table A - 7: Cooling Energy Savings Scenarios Analyzed for 42"x16" PTACs and PTHPs

Adoption Scenario	Effective Date	Electricity Savings EPCA 92 Baseline (Quads Primary)	Carbon Reduction EPCA 92 Baseline (Million Metric Tons)
1) Adopt 90.1-1999 Efficiency Level for small sleeve size products	January 2005	0.068	1.06
2) Adopt 90.1-1999 Efficiency Level for 42 x 16 products	January 2005	0.450	7.06
3) Adopt 90.1-1999 Efficiency Level for 42 x 16 products	January 2008	0.382	6.00
4) Develop Standard at Market Max Efficiency Level	January 2008	0.498	7.81
5) Develop Standard at Market Max Efficiency Level	January 2005	0.586	9.19
Scenario (4) – Scenario (2)	-	0.048	0.075

Table A - 8: Summary of Potential Energy Savings for Large (New Construction) PTACs and PTHPs – Cooling Mode

Category	Potential Energy Savings (quads)	
	Standard 90.1-1999 Relative to EPCA	Market Maximum Relative to Standard 90.1-1999
PTAC & PTHP - Cooling Mode New Construction (Large PTHPs)	0.450*	0.048**

* Assumes having an effective date for the adopted ASHRAE standard in 2005 with energy savings calculated to 2030.
** Values represent adopting the market maximum efficiency level in 2008 relative to adopting the Standard 90.1-1999 New Construction efficiency levels in 2005.

A-1.6 Energy Savings Potential for Small Sleeve Size PTHPs

The Department estimates the market for smaller-sleeve size heat pump products at a maximum of 15% of the entire PTAC/PTHP market, with a distribution among cooling capacities similar to the 42"x16" sleeve products. For the default baseline cooling mode energy savings analysis, DOE assumes that the replacement efficiency levels for small-sleeve size products are adopted in 2005. Savings from adoption of the Standard 90.1-1999 efficiency levels for small sleeve replacement PTAC/PTHP are calculated as

$$\text{Cooling Mode Energy Savings for Small Sleeve Size PTAC/HPs} = \left[\frac{0.15}{(1-0.15)}\right] \times 0.068 \text{ quads}$$

$$= 0.012 \text{ quads}$$

Maximum potential energy savings were estimated by assuming a "Market Max" efficiency level equivalent to the 90.1-1999 efficiency level for 42x16 products over a baseline of EPCA levels based on the estimated savings in Scenario 3 of Table A - 11 but applied to the 15% of the market represented by the smaller sleeve size products.

Accordingly, the energy savings over EPCA are estimated to be:

$$\text{Maximum Potential Cooling Energy Savings for Small Sleeve Size PTAC/HPs} = \left[\frac{0.15}{(1-0.15)}\right] \times 0.382 \text{ quads}$$

$$= 0.067 \text{ quads}$$

The cooling mode energy savings potential for pursuing a standard higher than 90.1-1999 level through rulemaking for these smaller sleeve size PTHPs is estimated at 0.055 quads (0.067-0.12).

Table A - 9: Summary of Potential Energy Savings for Small (Replacement) PTHPs – Cooling Mode

Category	Potential Energy Savings (quads)	
	Standard 90.1-1999 Relative to EPCA	Market Maximum Relative to Standard 90.1-1999
PTAC & PTHP - Cooling Mode Replacement (Small PTHPs)	0.012*	0.055**

* Assumes having an effective date for the adopted ASHRAE standard in 2005 with energy savings calculated to 2030.
** Values represent adopting the market maximum efficiency level in 2008 relative to adopting the Standard 90.1-1999 Replacement efficiency level in 2005.

Appendix A-2 Heating Mode Energy Savings Analysis

A-2.1 Background

The heating mode energy savings analysis develops the heating load estimates by using both heating and cooling data developed for the Screening Analysis.

A-2.2 Heating Load Estimates

The heating mode energy savings analysis uses the "No Economizer No Setback" (NENS) loads simulated as the basis for the PTAC/HP analysis work. The analysis divides the peak heating loads and peak cooling loads from the 7 buildings types simulated in the Screening Analysis by the floor space of the simulated buildings in order to establish peak heating and cooling load densities (in Btu/h-sf). In addition, the analysis divides the annual heating loads and annual cooling loads by the floor space for each building type in order to establish annual heating and cooling load densities (Btu/yr-sf). While these steps were undertaken for all buildings, only the lodging building type is used in the following steps of the heating mode energy savings analysis.

The heating mode energy savings analysis simulates each building type used in the Screening Analysis in 11 different climate locations. The analysis divides the annual heating load density from the lodging building simulation in each climate location by the peak cooling load density. This results in a ratio of annual heating load to cooling peak capacity that has the units of hours/yr, similar to the FLEOH used in the Screening Analysis. The concept of annual heating to cooling peak load ratio allows the estimation of the heating load faced by a space served by a given capacity PTHP equipment (assumed sized to meet the cooling load).

Using the mapping between climates and sub-census divisions described in the Screening Analysis TSD the heating mode energy savings analysis obtains a value for the annual heating load (Btu/yr) per unit of cooling capacity (Btu/h) for each sub-census division. The analysis then calculates a national average value for the annual heating to cooling peak load ratio based on the estimated shipment weightings for PTAC and PTHP products used for the revised cooling mode energy savings analysis. These weightings were based on estimates of the current stock and predicted growth of lodging facilities in 11 different sub-census divisions. While the distribution for PTHP products may be different than that for PTAC in general, DOE found no information source available that could be used to develop PTHP only shipments. For this analysis, DOE assumes the same shipment distribution for both.

The heating mode energy savings analysis uses the national average heating load per cooling capacity in place of the FLEOH in all of the energy consumption roll up tabs of the heating mode energy savings analysis spreadsheet (see Appendix A).

A-2.3 Equipment Efficiencies

The heating mode energy savings analysis casts the heating efficiencies in terms of annual average heating efficiency for products on the market. For simplicity, DOE has assumed that the heating load profiles faced by equipment used in lodging applications largely mirror the heating load profiles for residences and that the HSPF metric used to characterize the performance of residential heat pumps is a reasonable tool for estimating the annual heating performance of a PTHP. Further, DOE assumes that the relationship between HSPF and $COP_{47^\circ F}$ for a residential heat pump is similar to that for a PTHP product. The analysis uses these two assumptions in the estimation of the national heating energy savings for PTHP products.

The Department established the relationship between HSPF and $COP_{47^\circ F}$ for a residential heat pump through review of the ARI January 2003 Certification Directory. A regression analysis established the following relationship for small (<65,000 Btu/h cooling capacity) unitary equipment.

$$HSPF = 1.5843 \cdot COP + 2.4909 \qquad \textbf{(1)}$$

A plot showing this relationship is shown in Figure A - 1, below.

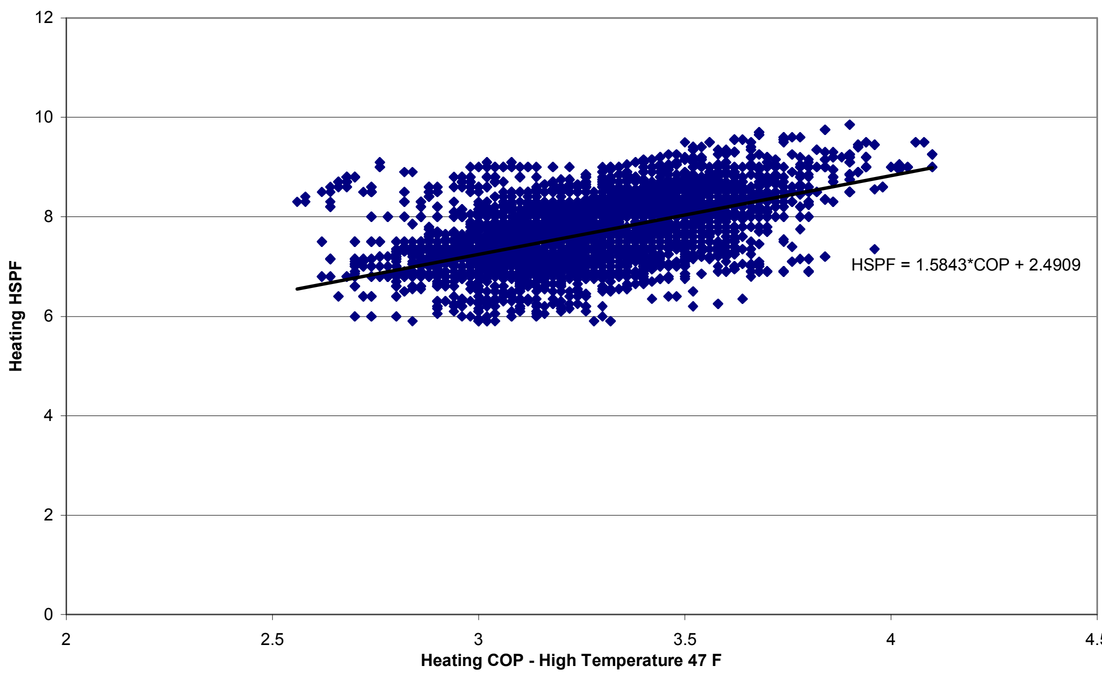

Figure A - 1: HSPF versus $COP_{47^\circ F}$ for Unitary Heat Pumps <65,000 Btu/h

Source: ARI Database for Unitary Products, January 2003, Split System: HP with Remote Outdoor Unit & Single-Package HP- Air-Source (ARI 2003c).[6]

Table A - 10 shows the $COP_{47° F}$ for the four different cooling capacity PTHP products analyzed in the heating mode energy savings analysis. The COP values for the EPCA efficiency level products are established by EPCA. The COP values for the Standard 90.1-1999 standard are established in that standard. The heating mode energy savings analysis bases the "maximum" COP values used in establishing the possible savings potential on the highest reported COPs in the ARI January 2003 directory for PTHP products in the identified capacity ranges. The product with the highest COP does not necessarily correspond to the product with the highest EER, but it does consistently represent either the maximum or very near the maximum EER available.

Table A - 10 also shows the corresponding HSPF values obtained from applying Equation 1. The heating mode energy savings analysis uses these resulting HSPF efficiencies as the basis for estimating the annual average heating performance for the different PTHP capacities.

Table A - 10: COP and HSPF Estimates for PTHP Products

Capacity Range (Btu/h)	$COP_{47° F}$			HSPF Estimate		
	EPCA	90.1-1999 42"x16" Products	Highest in ARI Directory	EPCA	90.1-1999 42"x16" Products	Highest in ARI Directory
<7,000	2.72	3.04	3.50	6.80	7.31	8.04
7-10,000	2.67	2.98	3.50	6.72	7.21	8.04
10-13,000	2.59	2.90	3.30	6.60	7.09	7.72
>13,000	2.54	2.84	3.10	6.52	6.98	7.40

Sources: EPCA and ARI for PTHPs.

A-2.4 Energy Savings Potential for Large Sleeve Size PTHPs

The heating mode energy savings analysis estimates the heating energy savings from adoption of the different heating efficiency levels in a fashion similar to the revised cooling mode energy savings analysis for the cooling mode. The national average ratio of annual heating load to cooling capacity replaces the cooling FLEOH. The estimated HSPF replaces the EER. For each equipment size (cooling capacity), the per unit heating energy consumption is estimated using the following equation:

$$Annual\ Unit\ Energy\ Consumption = \frac{National\ Average\ Ratio\ of\ Annual\ Heating\ Load\ to\ Cooling\ Capacity \cdot Cooling\ Capacity}{HSPF} \quad \textbf{(2)}$$

To maintain the basic structure of the cooling aggregation analysis spreadsheet, which covers both PTAC and PTHP equipment, the analysis assumes an HSPF of 3.413 Btu/W-h (corresponding to electric resistance heating) for all PTAC products. Since this electric resistance heating efficiency does not change between efficiency scenarios, it results in no heating energy savings for PTAC products.

The heating mode energy savings analysis multiplies the unit energy consumption by the estimated annual shipments for each capacity range for each year analyzed out to 2030. This is used to determine energy consumption for units shipped in each year.

The heating mode energy savings analysis calculates the total energy consumed for shipped products by summing the annual energy savings for each shipped product over the life of that product (assumed to be 15 years in this analysis). The Department received comments in response to the Screening Analysis that the in-service life of PTAC products was likely shorter than this value. However, for the purpose of this estimate of heating savings, the analysis assumes the same 15-year life used in the Screening Analysis and the revised cooling mode energy savings analysis.

The heating mode energy savings analysis calculates the source energy consumption based on the national average estimate for source energy conversion factors for electricity established by the EIA (AEO 2000) and used for the PTAC and PTHP cooling mode analysis. The analysis also uses the same electricity cost assumptions as those used for the PTAC and PTHP cooling mode analysis.

The Department examined four different scenarios for adopting a final rule. The heating energy savings for each scenario is shown in Table A - 11 and discussed below.

Table A - 11: Heating Energy Savings Scenarios Analyzed for 42"x16" PTHPs

Adoption Scenario	Effective Date	Cumulative Energy Cost Savings by 2030 ($ millions 1999)	Cumulative Primary Energy Savings by 2030 (quads)
1) Adopt 90.1-1999 Efficiency Level for small sleeve size products	January 2005	0	0.000
2) Adopt 90.1-1999 Efficiency Level for 42 x 16 products	January 2005	247	0.037
3) Adopt 90.1-1999 Efficiency Level for 42 x 16 products	January 2008	211	0.032
4) Develop Std. at Market Max Efficiency Level	January 2008	451	0.068
5) Develop Standard at Market Max Efficiency Level	January 2005	528	0.081
Scenario (4) – Scenario (2)	-	204	0.031

- Adoption of 90.1-1999 efficiency levels for small sleeve replacement products with a DOE effective date as a Federal standard by January 2005 results in a total estimated savings for the heating mode of PTHPs over current EPCA-efficiency products of 0-.0 quads of primary energy since the small sleeve size COPs do not differ from the EPCA requirements.

- Adoption of 90.1-1999 efficiency levels for 42"x16" products with a DOE effective date as a Federal standard by January 2005 results in a total estimated savings for the heating mode of PTHPs over current EPCA-efficiency products of 0.037 quads of primary energy by 2030.

- Adoption of 90.1-1999 efficiency levels for 42"x16" products with a DOE effective date as a Federal standard by January 2008 results in a total estimated savings for the heating mode of PTHPs over current EPCA-efficiency products of 0.032 quads of primary energy by 2030.

- Developing a Federal standard for Market Maximum efficiency levels for 42"x16" products with a DOE effective date as a Federal standard by January 2008 results in a total estimated savings for the heating mode of PTHPs over current EPCA-efficiency products of 0.068 quads of primary energy by 2030.

- Developing a standard for Market Maximum efficiency levels for 42"x16" products with a DOE effective date as a Federal standard by January 2008 results in a total estimated savings for the heating mode of PTHPs over current EPCA-efficiency products of 0.081 quads of primary energy by 2030.

- Estimated savings in achieving market maximum efficiency levels in 2008 over adopting 90.1-1999 in 2005 is 0.031 quads.

Table A - 12: Summary of Potential Energy Savings for Large (New Construction) PTACs – Heating Mode

Category	Potential Energy Savings (quads)	
	Standard 90.1-1999 Relative to EPCA	Market Maximum Relative to Standard 90.1-1999
PTHP - Heating Mode New Construction (Large PTHPs)	0.037*	0.031**

* Assumes having an effective date for the adopted ASHRAE standard in 2005 with energy savings calculated to 2030.
** Values represent adopting the market maximum efficiency level in 2008 relative to adopting the Standard 90.1-1999 New Construction efficiency levels in 2005.

A-2.5 Energy Savings Potential for Small Sleeve Size PTHPs

The Department estimates the market for smaller sleeve size heat pump products at a maximum of 15% of the entire PTHP market, with a distribution among cooling capacities similar to the 42”x16” sleeve products. For the heating mode energy savings analysis, DOE assumes that the heating efficiency for this fraction of the market could meet the Standard 90.1-1999 efficiency levels for 42” x 16” products by 2008. The baseline heating COPs for these smaller sleeve size PTHP products in Standard 90.1-2001 are the same as the current EPCA requirements. Since there is no change in efficiency levels, this analysis assumes that there are zero heating energy savings from adoption of the ASHRAE heating efficiencies for these products.

Energy savings for Market Max efficiency levels over EPCA levels are estimated based on the estimated savings in Scenario 3 of Table A - 11 (adoption of Standard 90.1-1999 efficiency levels for 42”x16” sleeve size products by 2008 over the current EPCA efficiency levels) for the 15% of the market represented by the smaller sleeve size products.

Accordingly, the energy savings for small sleeve size PTHPs are estimated to be:

$$Heating\ Mode\ Energy\ Savings = \left[\frac{0.15}{(1-0.15)}\right] \times 0.032\ quads = 0.006\ quads \qquad \textbf{(3)}$$

Therefore, the heating mode energy savings potential for smaller sleeve size PTHPs is estimated to be 0.006 quads.

Table A - 13: Summary of Potential Energy Savings for Small (Replacement) PTHPs – Heating Mode

Category	**Potential Energy Savings (quads)**	
	Standard 90.1-1999 Relative to EPCA	**Market Maximum Relative to Standard 90.1-1999**
PTHP - Heating Mode Replacement (Small PTHPs)	0	0.006*

* Values represent adopting the market maximum efficiency level in 2008 relative to adopting the Standard 90.1-1999 Replacement efficiency level in 2005.